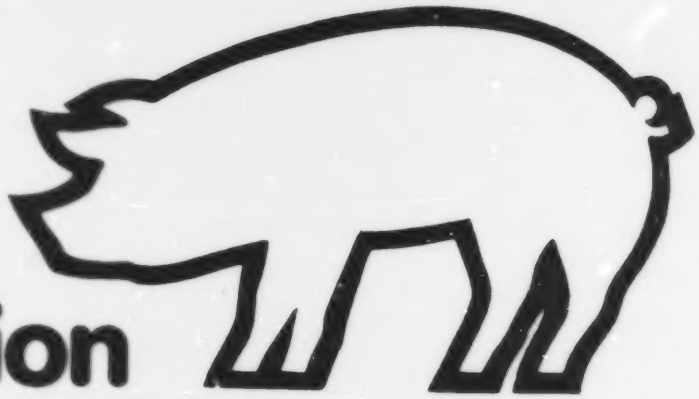
Agdex 440-51

Swine Nutrition



Manitoba Agriculture

BS-3067/

Contents

Introduction 1

Importance of nutrition in swine management 1

Digestion and absorption of nutrients 2

Digestion 2
Absorption 3
Digestibility 4

The major nutrients

Energy 4
Energy feedstuffs 7
Problem feeds 8
Feed analysis 9
Protein 10
Minerals 13
Mineral sources 17
Vitamins 17
Water 19
Feed additives 19
Use of sulfa drugs in hog feeds 24

Nutrient requirement tables 25

Ration formulation 26

All nutrients must be present 26
Factors to consider when purchasing feedstuffs 30
Feed testing for maximum use of feed resources 30
Feed formulation and balancing diets 31
The Pearson Square 31
Feed processing techniques 36
Feeding methods 37

Glossary 38

Swine nutrition

Introduction

This publication deals with defining, understanding and meeting the nutritional requirements of swine. It will provide the information necessary to accurately formulate rations to meet the nutrient requirements of various classes of pigs at different stages of growth and production. The digestive system of the pig, the five classes of nutrients and feedstuffs that are sources of each, a feed additives chart, nutrient requirement tables, diet formulation using the Pearson Square, and a discussion of alternative feeding methods are covered.

Importance of nutrition in swine management

Feed costs make up 60 per cent (farrow to finish operations) to 75 per cent (finishing only operations) of the total cost of pork production. A good working knowledge of the principles of nutrition, and an ability to apply them to feeding management, will benefit all swine producers in achieving maximum profits. Improved nutrition means increased net returns.

Animal nutrition is a dynamic field. Since the early 1900's researchers have identified several nutrients which affect performance. Recommendations are constantly changing as more research is conducted to accurately identify needs.

Many new feeds have been introduced. In the future, common feeds may become more expensive (example, soybean meal reaching $440/tonne) so that effective use of alternate feedstuffs may be profitable. On a global scale, the strong competition between humans and livestock for cereals makes it increasingly necessary to use feeds efficiently.

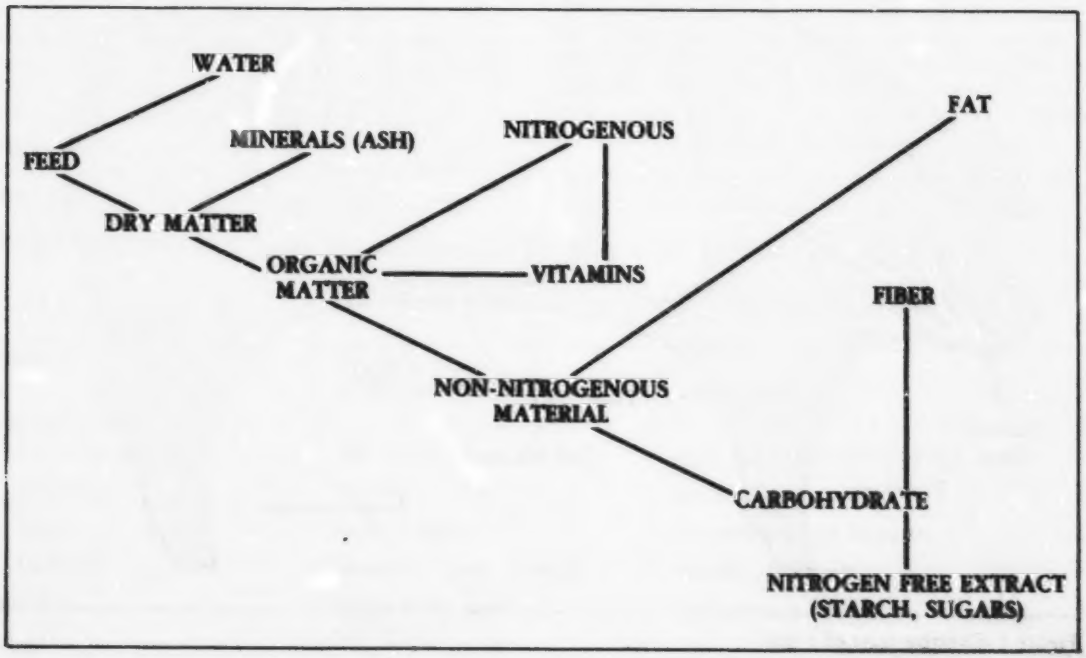
The basic concept of meeting the nutritional needs of animals is quite straightforward. All animals require only five components in their diet:

- energy
- protein
- minerals
- vitamins
- water

All feedstuffs can be broken down during feed analysis as illustrated in the diagram below.

This process results in:

- water
- minerals
- nitrogenous materials (proteins)
- fat, fiber, starches and sugar (energy sources)
- vitamins



Each nutrient has specific functions in the body, and each depends on the presence of other nutrients for proper functioning. A nutrient shortage or imbalance will adversely affect performance.

Pigs need a well-balanced diet for optimal reproduction and meat production. The pig is very sensitive to ration quality because they:

- grow quickly in relation to their body weight.
- make relatively little use of fibrous, bulky feeds (example - alfalfa hay, pasture) since they have a single stomach.
- are commonly raised in confinement and so all nutrients must be supplied in the ration.

Before discussing the function of nutrients, it is important to understand how the pig digests feed and absorbs nutrients from the feed digested.

Digestion and absorption of nutrients

Digestion is the preparation of food for absorption. It includes mechanical processes such as chewing (mastication) and muscular contraction of the stomach and intestines, as well as chemical action by enzymes in saliva and fluids produced by the stomach and intestines. The digestive process reduces food particles to a size and/or solubility that allows for absorption.

Absorption includes various processes which allow the tiny particles (molecules which are the end product of digestion) to pass through the membranes of the stomach and intestines. These particles are then picked up by the bloodstream for body cell use.

Digestion

The pig has a digestive system very similar to that of humans, except that the pig has a functional cecum. (Figure 1).

Mouth Digestion begins in the mouth. Food is chewed into smaller pieces (mechanical breakdown) to increase the surface area. This aids later chemical reactions with various digestive juices and enzymes. Saliva produced in the mouth moistens the dry feed so that it may be swallowed easily. At this point, the food is tasted. The taste of wormseed mustard, or badly-burnt feed, usually causes pigs to refuse to eat.

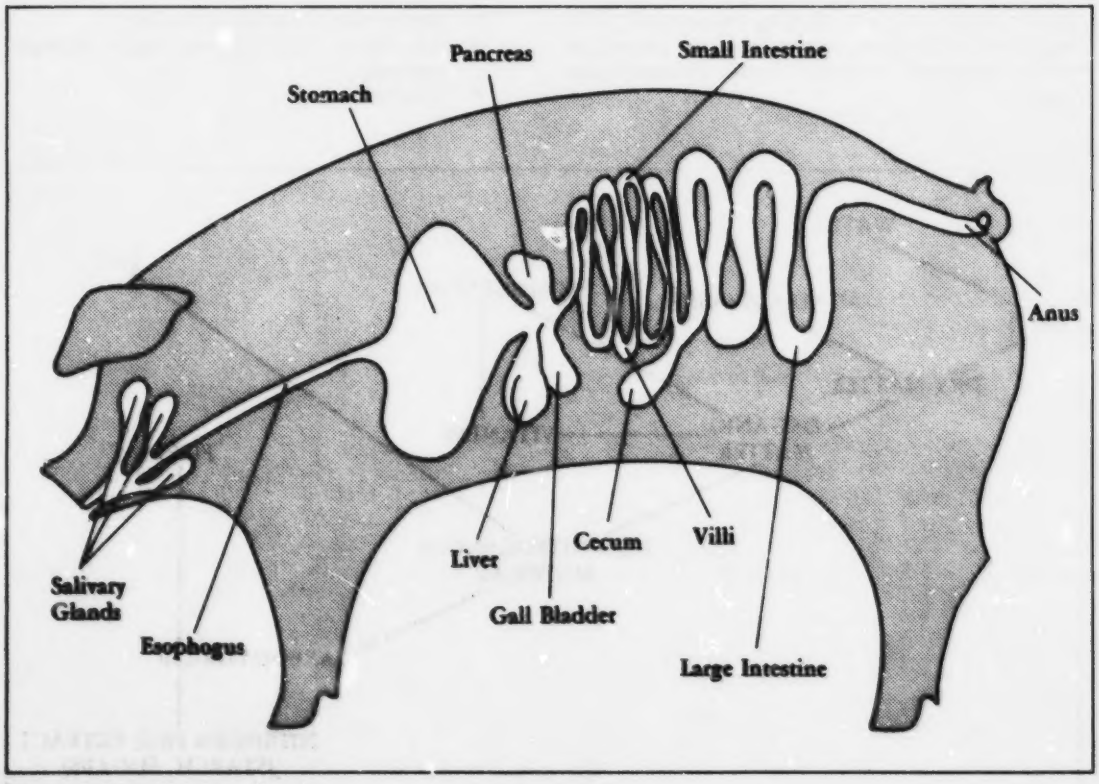


Figure 1 digestive tract of a pig

Saliva contains an enzyme called amylase, which helps to break down the starch component of feed into sugars. When swallowed, the food passes from the mouth to the stomach by means of a series of muscular contractions of the esophagus.

Stomach The stomach capacity of a 90 kg pig is six to eight litres. A constant churning action in the stomach further softens and separates food particles. The wall of the stomach produces gastric juices. These juices contain the enzyme lipase which acts on fats. Another enzyme, pepsin, breaks down protein. Pepsin can only function in an acid medium, which is produced by hydrochloric acid from the gastric juices. The acid also aids in killing disease organisms. In nursing pigs, the gastric juices also include the enzyme, rennin, which breaks down the protein in milk. One or two hours after eating, partially digested food in a semi-fluid form known as chyme moves on into the small intestine.

Small intestine The small intestine is a long tube-like structure which lies folded in the abdominal cavity. Its capacity is about eleven litres. Chyme is mixed with enzymes secreted by the lining of the small intestine, the pancreas and the liver. Bile acids are produced by the liver. These enzymes and bile acids break down carbohydrates, proteins and fats to molecules that may be absorbed into the blood.

Muscles in the thin wall of the intestine contract and relax, mixing the chyme and moving it toward the large intestine. During its passage through the small intestine, many nutrients are absorbed through the intestine wall into the bloodstream. Many finger-like projections, called villi, line the wall of the intestine. The villi increase the surface area of the intestine. Absorption takes place through the villi. Minerals and vitamins are not acted upon by enzymes. They dissolve in various digestive juices and water, and are then absorbed.

Large intestine The large intestine consists of two parts: a sac-like structure called the caecum, and the colon, which leads to the rectum. In the pig, the caecum is small and relatively useless (as compared to the horse, which has a large caecum). Here, the intestinal contents move very slowly and no enzymes are added. Some microbial breakdown of fibre occurs, but absorption is limited. Thus fibrous feeds, such as alfalfa, have limited feed value. Remaining nutrients, which dissolve in water, are absorbed in the lower part of the colon. Also, in the large intestine, much of the water from the intestinal content is absorbed into the body, and the feces are formed. The feces are later expelled through the anus. Digestion requires about 24 to 36 hours.

When nutrients (feeds) enter the digestive system, they must be transformed into a form which is useable by the body. Table 1 illustrates the conversion of feed nutrients into molecules that the body can absorb.

Absorption

Once nutrients are broken down by the process of digestion, they are ready for absorption into the pig's bloodstream. Some nutrients move across the cell membrane of the villi in the intestine into the bloodstream by the simple process of diffusion. Difussion is also known as passive transport. This occurs when there is more of a particular nutrient on the outside of the bloodstream than in the bloodstream. The result of this imbalance is an influx of nutrient molecules into the bloodstream.

In some cases the diffusion process does not provide sufficient absorption of a particular nutrient. Because of this, mechanisms have been developed in the body which actively take nutrients out of the intestine and put them into the bloodstream. This process is known as active transport.

Figure 2 shows the difference between passive and active transport systems.

TABLE 1. ACTION OF ENZYMES AND DIGESTIVE JUICES ON DIETARY NUTRIENTS.

Dietary Nutrient	Broken Down By The Action Of	To Produce Absorbed Form
Protein	protease, pepsin, trypsin and chymotrypsin	amino acids
Energy Sources:		
Fats (triglycerides)	lipase and bile acids	monoglycerides and free fatty acids
Starches	amylase	glucose
Sugar	dissaccharidases	monosaccharides (sugars)
Cellulose	bacteria in large intestine	volatile fatty acids
Minerals	hydrochloric acid and buffers	ionic state minerals

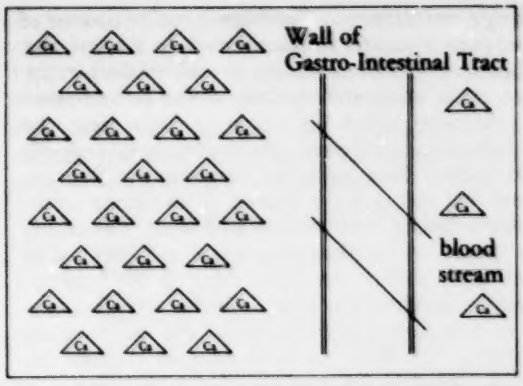
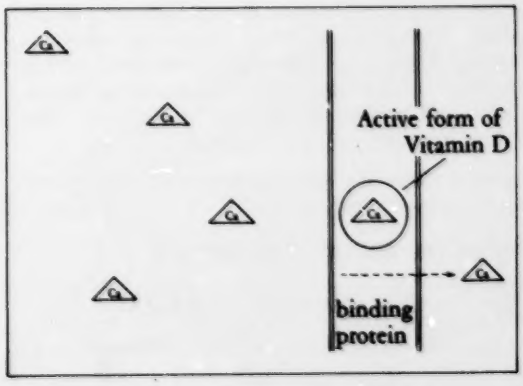


Figure 2 Passive and Active Transport Across Wall of the Gastro-Intestinal Tract (using Calcium as an example).

1. Where there is a lot of calcium in the diet, the calcium simply diffuses across the wall of the GI tract. (Passive Transport)

Explanation: when there are many calcium ions on one side and not many on the other, they tend to diffuse through the wall in sufficient quantities to meet nutritional requirements.

2. Where less calcium is present in the diet, the calcium gets assistance to move across the wall of the GI Tract (Active Transport).



Explanation: when calcium is relatively scarce, the body works to get enough. A calcium-binding protein grabs calcium and brings it across. Vitamin D is necessary for its formation.

If pigs are fed rations high in calcium, there is sufficient diffusion or passive transport across the gastro-intestinal tract to meet nutrient requirements. If there is a reduction in the amount of calcium in the ration or a significant increase in the amount needed (example, while milking), a reduced amount of calcium will be available for diffusion. In this case, unless the active-transport system is working at full efficiency, the amount of calcium entering the bloodstream may be insufficient to meet dietary requirements.

Once the nutrients enter the bloodstream, they are transported to various parts of the body to be metabolized. Metabolism is the use of absorbed nutrients by the animal to carry out vital body functions. Nutrients are used to:

- maintain life support systems (breathing, blood circulation and body movements).
- replace worn-out cells (maintenance)
- grow, produce a litter and secrete milk (growth and reproduction).

Digestibility

Only a percentage of each nutrient taken into the digestive system is absorbed. This percentage is called the digestibility coefficient. It is determined by animal digestibility experiments. Researchers determine both the amount of nutrient present in the feed and the amount of nutrient present in the fecal material (manure). The difference between the two, expressed as a percentage, is the amount digested by the pig. Each feedstuff has its own unique set of digestibility coefficients for all nutrients present.

The concept of digestibility is shown in Figure 3.

Imagine the digestive process as being similar to the effect seen when collecting water from a pipe with holes in it. All the water is added to one end of the pipe (mouth). Some water passes through to the other end of the pipe (anus). The remaining water leaks out the holes in the pipe. The percent water retained in the body is the digestibility coefficient.

In figure three 75 per cent of the protein in barley is digestible, and only 25 per cent is lost in the manure. Conversely, the crude fiber of barley is only eight per cent digestible and 92 per cent is passed into the manure.

The major nutrients

Energy

What is energy? Energy is the capacity to do work, and is required to carry out all body functions. Energy is the fuel of metabolism, in the same manner as gasoline is the fuel for cars. As in the burning of gasoline by cars, the use of energy in the body results in the production of heat. In nutritional use, energy is measured by heat production from biochemical oxidation in the animal's body, or the loss of energy through body excretion.

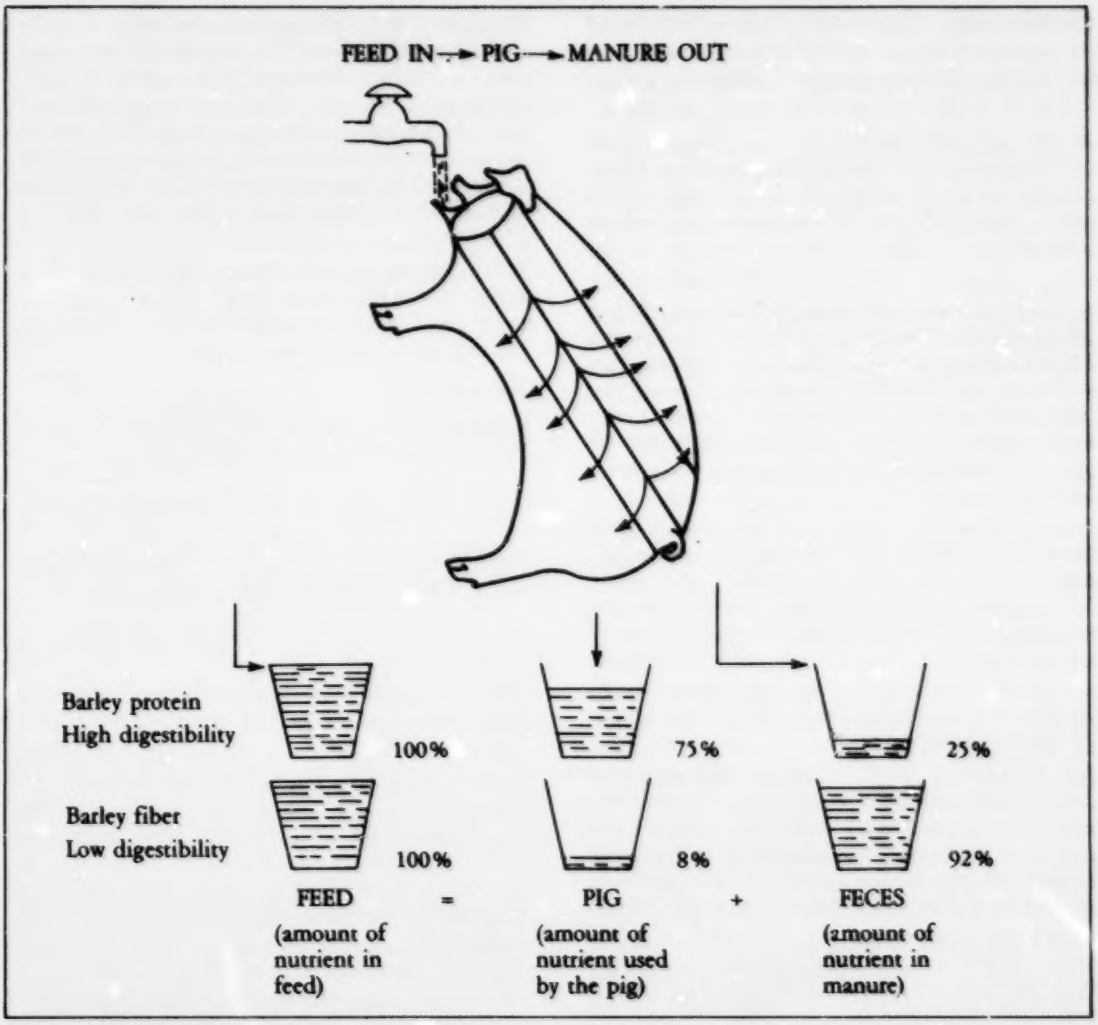


Figure 3 Digestibility of Nutrients in Barley

Energy is required in greater amounts than any other nutrient. The provision of energy accounts for the greatest percentage of feed costs. Energy is necessary for the maintenance of body tissues and formation of new tissues (growth, pregnancy and lactation). Small amounts of energy are stored as glycogen in the liver and muscles. Most of the energy in the body is stored as fat.

How is energy expressed? The unit of measurement used for energy is the calorie. A calorie is the amount of heat required to raise the temperature of one gram of water one degree Celsius. Commonly used larger units are the kilocalorie (Kcal = 1,000 cal) and the Megacalorie (Mcal) (1 Mcal = 1,000,000 calories or 1,000 Kcal). Gross energy content is determined by a laboratory analysis. However, not all the gross energy in food is useable by the pig. A more useful measure is digestible energy (D.E.), which is gross energy (G.E.) minus energy lost in the feces (fecal energy — the undigested portion of feeds) as seen in Figure 4. Digestible energy is the usable feed energy and is expressed in calories or kilocalories. It can not be measured in the laboratory. It can only be determined by feeding a pig, and measuring the total energy consumed and the energy lost in the feces.

Figure 4. Definition of Digestibility Energy

Gross Energy (G.E.) (Total energy in feed)
↓ → Fecal Energy
Digestible Energy (D.E.) (Usable feed energy)

The differences in gross energy content of some of the common feedstuffs are not large, but the digestible energy contents present a different picture (Table 2).

What supplies energy? In swine rations, cereals (grains) which usually make up 70 to 90 per cent of the total ration, are the primary energy source. Pigs use the carbohydrates, fats and proteins from grain as a source of energy.

Carbohydrates Carbohydrates in plants are present as sugars, starch and fibre. The contents of plant cells are primarily made up of soluble carbohydrates (starches and sugars). The plant cell walls are more structural, and therefore contain more fibrous carbohydrates, such as hemicellulose, cellulose and lignin (fibre). Starch and sugars are readily digested (the D.E. content of pure starch or sugar is about 4.0 Mcal of D.E./kg).

Fibre (cell wall constituent) is not easily broken down and in pigs, is generally considered undigestible. Young, fast growing pigs should receive rations low in fibre, or their growth rates will be depressed. Increasing the fibre level in rations results in reduced available energy, because the concentration of starch and sugar is reduced. Also, the fibre interferes with the digestion of starch and sugar. Bran is an example of a fibrous carbohydrate.

Fats Fats are a more concentrated source of energy than carbohydrates. Digestible fat furnishes about 2.25 times as much energy per kilogram as is contained in digestible carbohydrates. Animal and vegetable fats are almost equally effective additions to most livestock rations. Selection should be determined solely by comparative price. Soft fats (unsaturated) like soybean oil are more easily digested than hard fats such as beef tallow. Cereal grains contain small amounts of fat (wheat has three per cent while oats has five per cent fat). If using fat in swine feeds, add no more than three to five per cent as a general rule.

Proteins Protein supplies amino acids to build and repair body tissue. It is only used as an energy source when excess amounts are present in the feed. For protein to be used as energy, nitrogen is removed from the amino acids (de-amination). This process requires the elimination of the nitrogen as urea from the body. Since this uses energy, it is a less efficient method of obtaining energy than from carbohydrates.

Proteins are an expensive energy source. If barley is selling for $120/tonne, and soybean meal for $325/tonne, the same amount of energy (1 000 kcal) will cost more from soybean meal.

The calculation is:

Barley has 3,090 kcal D.E./kg, therefore, the cost of 1 000 kcal of D.E. from barley is 3.9¢:

$$\frac{120}{1000 \times 3.090} = 3.9¢/1\,000 \text{ kcal of D.E.}$$

Soybean meal has 3,350 kcal D.E./kg, therefore the cost of 1 000 kcal of D.E. from soybean meal is 9.7¢:

$$\frac{325}{1000 \times 3.350} = 9.7¢/1\,000 \text{ kcal of D.E.}$$

Therefore energy from soybean meal costs about 2.5 times more than energy from barley.

Factors affecting energy value of feeds

Amount of Soluble Carbohydrates and Fats The digestibility of the soluble carbohydrates, starch and sugars is about 95 per cent. The digestibility of animal fat is about 85 per cent. The higher the amount of these feed components, the higher the energy value.

Fibre

Type Fibre is made up of hemicellulose, cellulose and lignin (cell wall constituents). Hemicellulose and cellulose are partly digestible. Lignin is virtually undigestible.

TABLE 2. COMPARISON OF GROSS ENERGY AND DIGESTIBLE ENERGY CONTENT OF COMMON FEEDSTUFFS (AS FED BASIS — NRC 1979)

Feedstuff	Gross Energy (kcal/kg)	Digestible Energy (kcal/kg)
Wheat	4170	3480
Barley	3970	3090
Oats	4300	2870
Dehydrated Alfalfa Meal	4290	2580
Soybean Meal (44% Protein)	4220	3350
Canola Meal (37% Protein)	4300	3000

Digestible Energy level for barley would be expressed as 3090 kcal of D.E. per kilogram.

NOTE: Pigs eat to meet their energy requirement.

The fibre of young plants is more digestible than that of mature plants, as it contains a lower proportion of lignin.

Amount Fibre in a feed greatly affects energy digestibility. The higher the fibre content, the lower the energy content, because the concentration of starch, sugar and fat are reduced. High fibre levels also physically interfere with sugar, starch and fat digestion. Figure 5 shows the effect of fibre on energy digestibility.

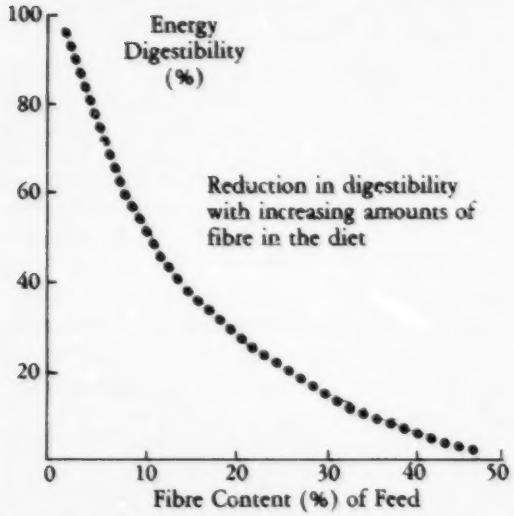


Figure 5. Energy Digestibility Versus Fibre Content

Since pigs eat to satisfy their energy requirements, higher fibre levels will lead to increased feed intake with poorer feed conversion efficiency. To some extent this depends on size, as older pigs can handle fibre better than young pigs.

Maximum recommended levels of crude fibre for various sizes of pigs are given in Table 3.

Feed particle size The particle size of cereal grain affects its digestibility. Grinding barley has been found to increase feed efficiency in pigs by nine per cent over whole barley. Crushing, grinding and rolling are equally effective when the grain is processed to the same degree of fineness.

Bushel weight Digestible energy levels of grain increase with bushel weight (Table 4). Grains of low bushel weight have higher percentage of fibre which reduces the digestible energy.

Energy feedstuffs

Barley Barley contains 3,090 kcal D.E./kg. This traditional Manitoba-grown cereal usually contains 10 to 12 per cent crude protein, and 6 per cent crude fibre. Barley is the major cereal in most rations fed to pigs in Manitoba. High-moisture barley is similar in feeding value to dry barley on an equal dry matter basis. Barley should be medium ground for all swine rations.

Oats Oats has 2 870 kcal D.E./kg. Oats should not be included in starter rations because of its high crude fibre level of 12 per cent. It is best used for breeding stock and finishing pigs. Oats usually contains 10 to 11 per cent crude protein. Fine grinding or removing hulls is recommended for oats. Oat groats (dehulled oats) is high energy feed (3,690 kcal D.E./kg). Oat groats and hull-less oats are excellent sources of energy for starter pig feeds.

Wheat Wheat has 3 480 kcal D.E./kg. It has a high digestible energy level, low fibre (3 per cent), good crude protein level (13 per cent), and is quite

TABLE 3. RECOMMENDED LEVELS OF CRUDE FIBRE IN THE RATION

Starter	3.5 - 4.0%
Grower	4.0 - 5.0%
Finisher	5.0 - 7.0%
Breeding Stock	6.0 - 8.0%

TABLE 4. EFFECTS OF WEIGHT PER UNIT VOLUME (BUSHEL WEIGHT) ON ENERGY LEVELS OF BARLEY GRAIN

Volume Weight of Barley		Digestible Energy Content
lb./bushel	kg/hectoliter	(Kcal/kg)
48	60	3090
46	57.5	3006
36	45	2880

palatable. Depending on cost, it may be only used in starter and early grower diets. Recently, utility wheats have been grown specifically for animal feeds. Coarsely grind wheat to avoid caking in feeders, and to prevent it from becoming pasty. Finely ground wheat is not readily accepted by pigs.

Corn Corn has 3 520 kcal D.E./kg. It is a high energy feed, low in crude fibre, and palatable. Crude protein content is low, with Manitoba grown corn normally ranging from 8.0 to 9.5 per cent. Recent research has shown that provided corn is mature when harvested, light bushel weight corn has the same feeding value, on a kilogram for kilogram basis, as heavy bushel weight corn.

Rye Rye has 3 310 kcal D.E./kg. When included in the diet of pigs weighing less than 25 kg, reduced gain and feed consumption have been observed. Rye included at up to 50 per cent of the grain in growing-finishing diets has resulted in acceptable gain and feed consumption. Rye often contains ergot. Do not feed rye containing ergot to bred or nursing sows. Rye containing over 0.1 per cent ergot should not be fed to any class of swine.

NOTE: *Grain containing 10 to 20 ergot bodies per litre has about 0.1 per cent ergot.*

Animal fats Tallow is a common animal fat used in swine rations. Its high digestible energy content (8 130 kcal D.E./kg) makes it an attractive means of increasing the energy content of rations, particularly those of young pigs. Fat, animal or vegetable, added to the ration will result in decreased feed intake and improved feed conversion efficiency. As a side benefit, supplemental fat reduces the dustiness of feeds and helps to lubricate equipment (example — hammers in a hammermill).

However, high levels of added fat can cause problems, including management problems (bridging in feeders) and nutritional problems (increased chance of spoilage by rancidity of the fat). Added fat is usually restricted to less than 5 per cent of the ration.

Although vegetable oils are easier to handle, tallow is generally less expensive and a more readily available source of fat.

Other feeds Other less commonly used energy feedstuffs include buckwheat, potatoes, bran, grain screenings, sugar and molasses, triticale, high moisture grain, bakery waste, and garbage. When planning to include an unusual feedstuff in your ration, have it analyzed for nutrient content. Consult with your regional swine specialist or swine nutritionist, on the use of the feedstuff.

Problem feeds

Moldy feeds All feeds grown under natural conditions contain the spores of molds. In the field, given the right temperature and moisture conditions, the spores will grow and produce moldy feed. This also happens in stored grain when the moisture content of the grain, or any part of it, is above 15 or 16 per cent for a period of time. As molds grow they use up some of the nutritive value of the feed, reducing available energy up to 25 per cent depending on extent of the molding. If mold growth is noticeable, the energy value has been reduced by an estimated 10 per cent. Mold also destroys many vitamins including A, D, E, K and thiamine.

Swine producers should be aware of diseases which may occur in swine that have eaten moldy feeds. The problem arises from the toxic materials, mycotoxins, that are produced by certain molds. About 100 molds that have been found to infect growing crops and stored feed, produce mycotoxins. Of these, about 20 have been identified with commonly occurring diseases in livestock.

Swine producers should be aware of the effects of two toxins, T-2 and zearalenone, in particular.

Zearalenone Upsets the reproductive system (Estrogenic Syndrome). In females, the vulva becomes swollen and in severe cases there may be rectal or vaginal prolapse. The uterus typically enlarges and becomes twisted. Infertility, small litters, weak piglets and higher frequency of mummified pigs at birth are all common disorders. In young boars, the testes shrivel and the mammary glands enlarge.

T-2 toxins These are produced by the Fusarium molds. Lesions form in the digestive tract, pigs go off feed, growth rate falls, and diarrhea, vomiting and internal hemorrhaging occur.

A cautious well informed approach is the best weapon when confronted with moldy feeds. Most molds do no harm other than reducing the nutritive value of the feed and making it unpalatable. Unfortunately, there is no way to distinguish between toxic and non-toxic molds by their appearance or color. Even though molds with the ability to produce toxins are present in a feed, they do not always produce mycotoxins. The absence of live toxin-producing molds does not guarantee that a feed is safe, because dangerous levels of mycotoxins may have accumulated earlier. Mycotoxins produced in the field are not destroyed during bin storage or ensiling, even though the mold that produced the toxins may no longer be growing.

If toxins are present, there is no practical method of removing them. If you suspect a problem, take these steps:

- contact a veterinarian or swine specialist to discuss any disorders.
- Avoid feeding suspect feeds to breeding stock.
- Do an at-home test to determine if a feed is causing unthriftiness. Offer the suspect grain to about 6 gilts in the 25 to 50 kg weight range. Compare their performance with similar gilts fed good feed. (This remains the most reliable test for mycotoxins).

Complete feed refusal will be noticed immediately, but it may be more difficult to determine reduced feed intake. Pigs may adapt to the factors causing reduced intake and return to normal intake.

Estrogenic Syndrome may be observed in about 5 to 10 days of feeding contaminated feed. If hogs vomit or develop bloody diarrhea, immediately discontinue offering the affected feed.

If there is no sign of disease the feed may be considered safe for feeder pigs. However continue to observe them closely for signs of mycotoxins.

If there are signs of disease:

- Reject the feed if —
  - — the hogs vomited or developed bloody diarrhea
  - — reduced feed intake or complete refusal occurred.
- If estrogenism occurred, do not feed to the breeding herd. Feed may be diluted with non-contaminated feed and fed to feeder pigs.

Feed analysis

Analysis by the Manitoba Agriculture Plant Pathology Laboratory will identify the presence of molds which may produce toxins, but will not comment on the possibility of mycotoxins in feed.

For mold analysis, take a sample of feed using normal sampling techniques and submit it to the Feed Testing Laboratory, Agricultural Services Complex, University of Manitoba. Since the mold must be grown before being examined, allow two to four weeks for processing. The Manitoba Agriculture factsheet *Feed Testing Services*, Agdex 400-50 provides this information.

Ergot Ergot is caused by a fungus which replaces the seed on the head of the plant. Ergot bodies have the same general shape as the seed, but are larger, purple to black in color on the outside, and greyish-white on the inside. Although most commonly found in rye, the fungus also infects wheat, barley, oats, triticale and numerous grasses.

The toxic compounds in ergot bodies include more than a dozen different alkaloids that have powerful pharmacological properties. The *individual and total* alkaloid contents may differ greatly. The level and kind of toxic effect depends upon the particular alkaloid and the species of livestock fed. Thus, of two samples each containing 0.1 per cent ergot, one may be toxic while the other may be safe for feeding. There is no readily available analysis for determining the potential toxicity of a sample of ergot.

When livestock are fed ergot contaminated feeds, a number of adverse physiological changes may occur including:

- behavioral effects including convulsions, muscle incoordination, lameness, difficult breathing, salivation and diarrhea
- dry gangrene and loss of extremities
- reproductive effects — abortion, altered reproduction rate and/or reduced lactation
- feeding effects — unpalatability, reduced feed intake and weight gain and increased feed: gain ratio
- death

The toxic symptoms are not general to all animals and a given effect depends upon various factors including species, ergot source, amount eaten and period of exposure.

In swine, classical signs of convulsion or gangrenous ergotism are usually not observed. The major effect is agalactia in sows if ergot is fed immediately before farrowing. Abortions do not occur, and most piglets are born alive. However, there is a high mortality rate due to malnutrition. Some gangrenous effects have been reported in the ear tips and tails of suckling piglets if the sow was fed ergot. Otherwise, development was normal.

In growing pigs fed ergot there is reduced feed intake and growth rates and an increased feed: gain ratio.

NOTE: *As a general recommendation, it is considered dangerous to feed any grain containing more than 0.1 per cent of ergot material (10 to 20 ergot bodies to a litre).*

If more ergot is present, mix the contaminated grain with clean grain to reduce the concentration. *Do not feed ergot contaminated grain to pregnant animals.*

Light-weight grain Many environmental and disease conditions affect growing plants so that the grain is light in weight per unit volume. Although the grain does not contain any substances harmful to animals, it contains lower levels of nutrients, especially energy, than normal grains. The energy content of heavy-hulled grains such as oats is depressed more than that of other grains such as wheat, which have little hull.

Contamination of the grain sample with chaff, bits of straw, or weed seeds, affect the density measurement without greatly affecting the digestibility of the energy. Poorly filled kernels, resulting from immaturity at harvest may have lower digestible energy content than well-filled grain of similar low weight due to contamination with chaff, etc.

For swine, supplementing the light-weight grains with vegetable oil or animal fat may be necessary. Another alternative is to mix the grain with plump undamaged grains to raise the energy of the ration to acceptable levels. It is especially important to feed grain according to weight, not volume.

Frozen or immature grain When grain is frozen or harvested before maturity the amount of starch it contains is reduced. This grain is relatively high in bran and low in available energy.

Sprouted grain Sprouting lowers the yield and the weight per unit volume, but the grain is not harmful to livestock. The amount of sprout growth indicates the extent of loss in feed value; the longer the sprouts, the greater the loss. The feeding value of sprouted grain is similar to that of light-weight grain caused by other conditions. Care must be taken to ensure that sprouted grain is dry enough to store without molding.

Smut Smut on grain is not generally considered poisonous to animals. However, grain containing a lot of smut should be introduced into the ration gradually. Follow the procedure for introducing moldy feeds as smut has occasionally caused problems.

Rust Kernels of rust-infected grain do not fill properly. In this respect they are similar to the kernels of frozen and immature grain. Although rust spores are not toxic, dustiness produced by large quantities of spores may affect palatability. Follow suggestions for feeding light weight grain.

Raw soybeans Raw soybeans contain factors that reduce the nutritional value of feeds and should not be fed to simple-stomached animals such as pigs.

Potatoes Cook potatoes before feeding to pigs. Do not feed potatoes that are either sunburnt or sprouted as they contain toxic glycoalkaloids.

Newly harvested grain There is no reason why newly harvested grain should cause problems. Occasionally, there are reports of losses and some feeders refuse to use new grain until after a month or so of storage.

Protein

Proteins are known as the building blocks of the body. They are primary constituents of many structural and protective tissues such as bones, ligaments, hair, skin, and especially the soft tissues including the organs and muscles. Protein is the nutrient found in highest concentration (other than water) in organs and muscle tissue. As there are no proteins in fat, the total protein content of animal bodies ranges from about 10 per cent in fat mature animals to 20 per cent in lean young animals. Thus the young growing animal has the highest requirement for protein when expressed as a percentage of the diet. Production factors, such as gestation and lactation, greatly increase the protein requirement because of the needs of the fetus, and for milk protein production.

Proteins are organic compounds formed from amino acids, which are present in characteristic proportions for each specific protein. Protein can be compared to a chain, with amino acids as the links. There are 23 known amino acids.

When food is eaten, the protein is broken down into its amino acid components during digestion. These amino acids are then absorbed from the small intestine and distributed by the bloodstream to the body cells, which rebuild these amino acids into body proteins.

The joining of amino acids into proteins (protein synthesis) is not a random process. Rather, it is a detailed predetermined procedure. Each cell contains information concerning the sequences of amino acids for the various proteins to be synthesized in the cell. Amino acids are linked to form a specific protein which has its own particular function in the body.

For a protein to be synthesized, all of its constituent amino acids must be available in sufficient quantity. If one amino acid is missing, the protein synthesis is halted. When a particular amino acid is deficient, it is referred to as a limiting amino acid because it limits the synthesis of protein. This is why protein quality is so important in the nutrition of non-ruminants. In ruminants, all essential amino acids are synthesized by microbes in the rumen. These microbes pass down the gut and are digested and absorbed, providing ruminants with all amino acids. Non-ruminant animals like pigs have the ability to synthesize a limited number of amino acids in the

liver and kidneys. However, there are 10 amino acids which are required by the body which cannot be synthesized by pigs. These must be supplied in sufficient quanitities in the ration to meet the pig's requirements. They are referred to as dietary essential amino acids (Table 5).

TABLE 5 DIETARY ESSENTIAL AMINO ACIDS

Lysine	Arginine
Valine	Threonine
Methionine	Tryptophan
Isoleucine	Phenylalanine
Leucine	Histidine

Feedstuffs vary in their ability to provide these essential amino acids. Certain feeds are deficient in particular amino acids. For example, corn is deficient in lysine. Other feeds such as soybean meal and fish meal contain high quality protein which, when digested, provide balanced supplies of the various amino acids in ratios necessary for protein synthesis. Pigs can be fed protein sources that are not readily acceptable as human food, such as fish meal, and by-products of vegetable oil production (soybean meal, canola meal) and animal processing (meat meal, feather meal).

Cereal grains alone contain enough of the 10 essential amino acids to satisfy many of the pig's requirements. Lysine, methionine, and possibly threonine may be limiting in barley, oats and wheat. In corn, tryptophan may also be limiting.

A pig's performance will depend upon adequate levels of essential amino acids, and the balance between the various individual amino acids. A shortage of one will cause the pig to grow to the level determined by the amino acid in shortest supply; the "first limiting" amino acid. In the case of barley, this is lysine. Barley contains an average 0.4 per cent lysine. The requirements for lysine by all sizes of pigs is greater than that found in barley. Barley alone can supply 57 per cent of the growing pig's requirement, (25 to 60 kg) and 70 per cent of the finishing pig's requirement (60 to 100 kg). If not supplemented, rations consisting only of barley will result in poorer growth.

When these rations are used, incorporate protein supplements containing the necessary amino acids into the diet to compensate for the deficiency of the particular amino acid(s). This could be done, for example, by incorporating certain levels and combinations of soybean meal, canola meal, peas, etc. Some synthetic forms of amino acids are available, but commercial supplies of all individual amino acids needed may not be available. Therefore, it is necessary to use natural protein sources. Base protein or amino acid supplementation on providing enough of all essential amino acids to meet the pig's requirement. Good growth and performance by swine in the most economical manner will result.

Factors affecting protein digestibility of feeds

Protein digestibility in most common feedstuffs ranges from 75 to 90 per cent. It is not enough to have a high protein feedstuff if the protein is not usable by the pig. Digestibility can be affected by various management practices.

Type of protein The importance of digestibility is brought into focus when feather meal, which contains 85 per cent protein but is only about 25 per cent digestible, is compared to a conventional diet such as barley plus soybean meal that is about 80 to 85 per cent digestible. Evaluation based solely on total protein content makes feather meal look attractive. Because of low digestibility, poor growth results when feather meal is used in large amounts in pig feeds.

Effect of fibre As in the case of energy, feeds like straw, corn silage and alfalfa, which are high in fibre, may not provide much usable protein for the pig. In the case of straw and corn silage, the protein content is not high to begin with. In alfalfa, the protein level is high, but as is the case in all feeds with high fibre content, the protein is poorly digested.

Effect of grinding Unground feed such as whole grain reduces the opportunity for protein digesting enzymes to act. Thus, potentially usable protein passes through only partly digested. Smaller particles provide a larger surface area for enzymes to act upon.

Heat treatment Heat is used during some manufacturing processes. The more heat used, the less digestible the protein. Blood meal is a prime example of a protein source with poor digestibility due to denaturation of the protein by heat.

Protein inhibitors Several plant products contain compounds (inhibitors) which prevent protein digesting enzymes from working. This reduces protein digestion. For example:

- Raw potatoes contain chymotrypsin inhibitors, which reduce protein digestion. However, cooking the potatoes inactivates the inhibitors.
- Raw soybeans contain a trypsin inhibitor. Protein is less available in raw soybeans than in roasted soybeans. The trypsin inhibitor prevents the enzyme trypsin (secreted in the gastrointestinal tract) from reducing the protein to amino acids. Heating (roasting) destroys the trypsin inhibitor.

Non-protein nitrogen (NPN)

Ruminants are commonly fed non-protein nitrogen such as urea, which is converted by microbes in the rumen into useable protein. Because of the difference in the digestive system, the pig cannot really make use of non-protein nitrogen and thus it should not be included in the diet.

Meeting amino acid requirements

This can be done in one of four ways:

- Add a commercial protein supplement (example 35 to 40 per cent or 42.5 per cent crude protein supplement) which contains minerals and vitamins.
- Add a high protein feedstuff (example, soybean meal or fish meal) and a vitamin-mineral premix.
- Add particular amino acids to meet the pig's requirement when home grown feeds, such as barley and peas, are fed, and only one or two supplemental amino acids may be required. Minerals and vitamins are supplied in a premix.
- Buy a complete feed containing the required protein level.

Protein feedstuffs

Soybean meal Consistency in quality and quantity of amino acids has made soybean meal, at either 44, 47.5 or 50 per cent crude protein, the standard source of protein in swine rations. Pigs perform satisfactorily on a barley-soybean meal diet fortified with minerals and vitamins. Unfortunately, our climate is unsuitable for growing present varieties of soybeans. A strong dependency upon the U.S. crop is necessary. Although not generally a serious problem, a fluctuation in supply of U.S. soybeans is certainly reflected in the cost of our swine rations. Other protein feedstuffs can be substituted, depending on cost and supply.

Unprocessed canola seed and canola meal With the development of the double-low rapeseed varieties referred to as canola, (low glucosinolates and low erucic acid-Tower, Candle, Regent and Altex), canola meal has become a better substitute for soybean meal. The current recommendations for use of the double-low canola varieties are 7.5 per cent of the total ration for starting pigs (5 to 25 kg), 10 per cent for growing pigs (25 to 60 kg), and complete protein substitution in breeding stock and finishing pig rations.

Be sure that the Canola meal has been made from double-low varieties. If the old varieties of rapeseed are used, either whole or as a meal, do not use more than five per cent in diets for starting, growing and finishing pigs, or more than three per cent in diets for sows.

Pigs can be fed grain contaminated with canola. Up to 15 per cent whole seed of Candle variety (double-low variety) was fed to growing-finishing pigs, with acceptable results. If the rapeseed can be identified as a double-low variety and used at recommended levels, feeding problems should not occur. If the rapeseed is the "old type", care should be taken when feeding. Limit the use of grain contaminated with more than 6 per cent "old type" rapeseed, or clean out the rapeseed before use.

Field peas Field peas grown in Manitoba reduce the dependency on imported soybean meal. In addition, they can be an important alternative in the cropping rotation. Field peas are a good source of both crude protein (24 per cent) and energy (3 530 kcal D.E./kg). Research conducted at the University of Saskatchewan determined that field peas could replace all of the protein from a soybean-fish meal supplement, with no difference in overall performance by growing and finishing pigs. Field peas can generally be used at a level of 20 to 25 per cent of the total ration. It is advisable, however, to have field peas tested for protein content, as they can vary from 10 to 30 per cent.

Fababeans The use of fababeans (about 26 per cent crude protein) as a "home grown" protein supply has created some interest in Western Canada. However, improvements in maturity (currently 100 to 110 days), reduction in shattering and better disease resistance, must be incorporated into the present varieties to make fababean production more practical.

University of Manitoba studies have shown that fababeans can be used as the sole protein supplement in swine rations for grower-finisher pigs (starting weight 35 kg or more). The recommended substitution rate is 5 per cent fababeans for 2.5 per cent grain and 2.5 per cent soybean meal (44 per cent protein). Some studies have shown reduced weight gains when fababeans were used in rations for pigs under 35 kg. Work at the University of Alberta has shown satisfactory results with pigs weighing 10 kg to 35 kg when up to 20 per cent of the ration was replaced with fababeans. Because of the need to accurately supplement the fababeans with other protein sources, it is usually more practical for producers to use a commercial mix for pigs in the 10 to 35 kg range, where feed consumption is low. Fababeans should be restricted to not more than 10 per cent of the diet for gestating and lactating sows. This is not usually a problem because of the relatively low level of supplementation in these rations.

Meat meal Meat meal is a cooked and sterilized by-product of the meat processing industry. It is a good source of calcium and phosphorus, two important minerals in swine nutrition. However, the digestibility of the protein in meat meal varies greatly. The availability of methionine and lysine varies greatly depending on processing. Variability in the feeding value and limited availability make meat meal most advantageous when incorporated in protein supplements combined with other high protein feedstuffs.

Blood meal The crude protein content of blood meal is around 80 per cent. Due to the high temperatures used in processing, the protein is poorly digested and of poor quality. Therefore, blood meal should be limited to 1 per cent of the diet.

Fish meal Fish meal is a high quality protein source with an excellent balance of amino acids. It is also a good source of calcium and phosphorus. Cost usually limits its use to creep-starter feeds.

Dairy by-products (skim milk.) Scouring can be a problem in milk feeding if precautions are not taken to feed at regular intervals. Milk should either be fresh or always at the same degree of sourness and attention should be paid to the cleanliness of the equipment used for feeding. The feeding program in Table 6 may be used as a guideline.

Dried skim milk Dried skim milk is similar to liquid skim milk, but about 10 times more concentrated. Cost makes dried skim milk uneconomical, with the possible exception of creep-starter rations.

Whey, a by-product of cheese making generally creates a costly disposal problem for processing plants. It is a bulk feed (93 per cent water) and contains less than 1 per cent protein, although the protein is of excellent quality. A recent Alberta Agriculture study evaluated the handling and feeding of liquid whey to growing and finishing pigs under commercial conditions. Pigs fed barley, with added minerals and vitamins, and whey free-choice, grew as well as pigs fed a barley-soybean meal diet with water free choice. The dry matter in liquid whey can be used to supply up to 30 per cent of the total diet (or about 7 to 14 litres per head daily, depending on body weight).

Alfalfa meal Some factors restrict the use of alfalfa meal as a supplement including:

— It contains about three-quarters as much digestible energy per kilogram as barley;

— Although the crude protein level is around 17 per cent, only about half is digestible, while barley at 11 per cent crude protein is about 75 per cent digestible. The maximum level of alfalfa meal in nursing sow rations is 10 per cent and in dry sow rations, it is 25 to 30 per cent. Alfalfa should be restricted to not more than 5 per cent of finisher rations. It should not be used at all in other rations. Cost of alfalfa in relation to its digestibility and the lower cost of nutrients in barley generally make the use of alfalfa meal uneconomical.

Sunflower meal Sunflowers now rank second to soybeans as a world source of edible oil. Dehulled sunflowers produce a meal containing about 12 per cent fibre and 42 per cent crude protein. The lysine content is quite low compared to levels in other oilseed meals. Consequently, sunflower meal is not suitable as the only source of supplementary protein and should be used only in rations for finishing pigs or gestating sows. Sunflower meal can replace 25 to 50 per cent of the soybean meal in these rations, with research indicating 25 to 30 per cent as the most favorable replacement level.

Minerals

The pig requires at least 14 minerals, essential for:

- constituents of bones and teeth
- components of enzymes
- components of proteins, organs and blood
- muscle and nerve functions
- maintaining metabolic processes.

Minerals required in large amounts are known as *macro*-minerals. These include calcium, phosphorus, sulfur, sodium chloride, potassium, and magnesium.

TABLE 6. FEEDING RECOMMENDATIONS FOR PIGS FED SKIM MILK

Pigs' Weight (kg)	Barley & Premix to Skim Milk Ratio	Barley & Premix* (kg)	Skim Milk** (kg)
20-40	1:4	.6 - 1.1	2.3 - 2.7
40-60	1:3	1.2 - 1.6	3.2 - 3.6
60-100	1:2	2.3 - 2.5	3.6 - 4.1

*The barley premix should consist of 95 per cent barley and 5 per cent premix. The premix should contain calcium, phosphorus, iron, zinc, iodine, selenium, sodium chloride (salt) and Vitamins A, D and E.
**One litre of skim milk weights about 1 kg.

Minerals required in small amounts are called *micro* or trace minerals. These include iron, zinc, copper, manganese, iodine, fluorine and selenium.

Under natural conditions, pigs obtain large amounts of their mineral requirements by eating pasture and "rooting" in the soil. Under confinement conditions, pig rations must be supplemented with minerals. Knowledge of the actual requirements and factors affecting availability of minerals for the pig is limited. Relative to energy and protein, minerals are inexpensive. At little additional cost, they can be added to rations, as a precautionary measure to ensure satisfactory results.

The mineral requirements for swine recommended by the National Research Council are given Table 7. These should be viewed as minimum requirements.

There is also a danger in adding excessive amounts of minerals to swine diets. *More isn't always better!* Interrelationships among minerals in the diet are very complex. For example, too much calcium will result in an improper calcium-phosphorus ratio and may limit zinc availability. Also, high levels of certain minerals can be toxic as shown in Table 7.

Minerals normally added to swine feeds

In Manitoba, at least seven minerals are limited in locally grown feed ingredients, and should always be added to swine feeds. These are:

Calcium and phosphorus About 70 per cent of the minerals in the body are calcium and phosphorus. Grains supply very little calcium and

TABLE 7. MINERAL REQUIREMENTS FOR SWINE[1]

Mineral	Unit	Class of Swine							
		Starting	Growing - Finishing			Breeding Stock			
		10-20 kg	20-35 kg	35-60 kg	60-100 kg	Bred Gilts, Sows & Boars	Lactating Gilts & Sows	Toxic Dietary	Age
Calcium	%	0.65	0.60	0.55	0.50	0.75	0.75	1% (with limited zinc) 1% (with adequate zinc & limited phosphorus)	Immature Immature
Phosphorus	%	0.55	0.50	0.45	0.40	0.60	0.50	—	
Salt[2]	%	0.40	0.40	0.40	0.40	0.4	0.5	1-2% (with severe water restriction)	All ages
Copper	ppm[3]	5.0	4.0	3.0	3.0	5.0	5.0	300-500 ppm (in absence of higher levels of dietary iron & zinc)	Immature
Iodine	ppm	0.14	0.14	0.14	0.14	0.14	0.14	800 ppm	Immature
Iron	ppm	80	60	50	40	50	50	5000 ppm	Immature
Manganese	ppm	3.0	2.0	2.0	2.0	10	10	4000 ppm	Immature
Selenium	ppm	0.15	0.15	0.15	0.10	0.15	0.15	5-8 ppm 10 ppm	Immature Breeding Sows
Zinc	ppm	80	60	50	50	80	80	2000 ppm	Immature

1. Information from National Academy of Sciences — National Research Council Publication "Nutrient Requirements of Swine" - 1979.
2. Recent research suggest that 0.25-0.30% salt is adequate in growing-finishing pigs.
3. ppm — parts per million (mg/kg).

although the phosphorus level in grains is high, only about one-half is available to the pig.

The requirements for calcium and phosphorus depend on:

Amounts of each present

— The presence of adequate amounts of each mineral in the diet (Table 7). This table outlines the ***minimum requirements*** for various stages of growth and reproductive performance. It is important to provide rations with adequate mineral levels at each stage of development if maximum performance is to be achieved.

Calcium — phosphorus ratio

— A correct ratio (balance) of calcium to phosphorus. An improper ratio can result in one mineral impairing the function of the other, thereby bringing about depressed growth rates and sub-standard performance. Ideally, the ratio of calcium to phosphorus is 1.2:1, but may range between 1.5:1 and 1:1.

Levels of vitamin D

— Vitamin D is involved in the absorption of calcium and phosphorus. A deficiency in Vitamin D can lead to inadequate absorption, while excesses can lead to poor growth rates and the deposition of calcium (calcification) in the heart, lungs and kidneys.

A deficiency of calcium or phosphorus can result in rickets. Symptoms are stiffness, unthrifty condition, poor growth, and enlarged painful joints. In growing animals, large bones may be twisted, bent or broken.

During mid or late lactation, *Osteomalacia* may occur in sows. Calcium is removed from the bones to meet the demands of milk production if enough calcium is not supplied in the diet. Symptoms include lameness and stiffness in the hindquarters, and possible fractures of the pelvic and leg bones.

NOTE: ***Dietary calcium and phosphorus requirements are higher for maximum bone development than for gain and feed efficiency. For weanling pigs (10 to 20 kg) and developing boars and gilts (potential herd replacements), it may be important to feed greater calcium (0.85 to 0.90 per cent) and phosphorus (0.65 to 0.70 per cent) levels for sound skeletal development. However, no amount of extra calcium and phosphorus will correct structural unsoundness (straight shoulders, buckled knees, too-straight hind legs, extreme arch,) that often impair breeding usefulness.***

Higher mineral levels should also be considered for pregnant sows on a restricted daily feed intake of 1.8 kg. Calcium and phosphorus requirements are higher for sows with longer lactation periods and with an increasing number of litters.

Sodium and chlorine (salt — sodium chloride) Salt is a combination of two elements, sodium and chlorine. Both sodium and chlorine are essential for normal body functions. Chlorine combines to form hydrochloric acid, a major chemical responsible for breakdown of food in the stomach. A deficiency of salt can result in loss of appetite and weight. The kidneys regulate levels of salt in the body by excreting excess amounts. Salt poisoning is rare, but may occur if a large amount of salt is eaten without a sufficient water supply being available.

Although salt occurs naturally in feedstuffs, added salt is required. Add salt to swine rations at a rate of 0.25 to 0.50 per cent. Producers who use lagoon water to fertilize crops should use the 0.25 per cent recommendation. Salt excretion through the feces is directly correlated to the dietary intake. In times of high evaporation rates, the salt content of swine wastes becomes more concentrated, which limits their use on crops. Salt is also commonly used as a carrier for other minerals such as iodine and cobalt.

Iron Iron is needed in the formation of hemoglobin (contained in red blood cells) which carries oxygen to various parts of the body. A deficiency of iron will produce anemia in young pigs and reduce efficiency and growth rate. In older pigs, rations usually have adequate levels of iron, so anemia is rarely a problem.

Newborn pigs have very low stores of iron in their bodies. Since sow's milk is low in iron, baby pigs on a milk diet will often develop anemia, unless iron supplementation is provided. Signs of anemia are poor growth, rough hair, wrinkled skin and paleness, and occasionally, laboured breathing (thumps). Sudden death may occur.

Feeding iron to the sow during lactation will not increase iron levels in milk. Iron must be made available to piglets until they eat the normal dry ingredients of a swine ration.

NOTE: To prevent anemia in young pigs, a suitable ***iron preparation must be administered within four days of birth.*** Iron may be supplied in the following ways:

- Iron dextran and other iron-carbohydrate complexes may be injected intramuscularly at three days of age. A second dose may be required if the pigs do not start to eat at an early age. This is the

surest and preferable way of supplying iron.

- In the form of "reduced iron". An oral dose is estimated to be the amount which would cover half a ten cent piece. The first dose should be given when the piglets are three days old, and repeated weekly for three weeks. Adding fish oil to the iron can prevent dry reduced iron from going into the lungs.
- In commercial preparations, where iron is incorporated with copper for oral use. Directions are the same as for an oral dose for reduced iron.

Iron requirements for growing pigs are not precisely know. However, 50 milligrams per kilogram (mg/kg) or 50 parts per million (ppm) in the ration, have been suggested. Only a small percentage of feed samples are expected to contain less than the requirement of iron for swine.

Zinc A deficiency of zinc causes *Parakeratosis* in swine. The condition is most common in young, confined pigs. The symptoms are slow growth, reduced appetite and a skin condition which looks like mange. The skin reddens and eruptions occur, with a secretion of a dark watery substance. Scabs develop. In borderline deficiencies, a fading or bleaching of hair color may be seen. Litter size in sows may be reduced.

Growing pigs require 50 to 100 mg/kg (50 to 100 ppm) of zinc in their diets. Because cereal grains may be deficient in zinc, supplementation is required.

Iodine A deficiency of iodine is most critical in sows and very young pigs, but all rations should contain 0.2 mg/kg. Iodine is needed by the pig for growth, reproduction, and thyroxine production. Thyroxine controls the rate of metabolism in the body. If iodine is deficient, the thyroid gland, which produces thyroxine, enlarges. The enlargement can be recognized as goitre.

Pregnant sows that are iodine deficient usually go full term, but their offspring may be born hairless and will often die within a few hours of birth. Iodine must be added to the ration.

The use of iodized salt (red), cobalt-iodized salt (blue) or trace mineralized salt in swine rations will provide adequate iodine. Do not use white salt as it contains no iodine.

Minerals not always added but of importance

Copper Copper is essential for a number of enzyme systems, and the synthesis of hemoglobin in red blood cells. Liver stores of copper are low in the new born pig. Therefore, the young piglet may require a copper supplement. (Note oral supplementation procedures for iron). For adult swine, dietary supplementation may be required as Manitoba grains may be deficient in copper. A diet containing 6 mg of dietary copper per kilogram of diet is adequate.

Selenium Only recently has the need for selenium in swine rations been confirmed. From available research, the minimum level of selenium recommended for growing and finishing swine, is 0.1 mg/kg (0.1 ppm). Levels greater than 8.5 ppm are considered toxic. In Manitoba, selenium levels are expected to be adequate; however, certain parts of the province may be low in this trace mineral. Deficiency symptoms are associated closely with those of Vitamin E. The following conditions result from a selenium deficiency:

Mulberry heart disease

- Most commonly occurs as sudden death in feeder pigs (usually those that were doing very well).
- Occasionally death is preceeded by depression, muscular trembling, labored breathing, and high temperature.
- The skin on the legs and ears may be discolored.

Hepatosis dietetica (Liver Necroses)

- Is characterized by sudden death due to liver damage and hemorrhage. It may occur with Mulberry Heart Disease.
- Rapidly growing pigs are most commonly affected.

Cobalt Cobalt is necessary in the production of Vitamin B_{12} in the gut. If adequate Vitamin B_{12} is present, there is probably no need for additional cobalt. However, most swine diets contain 0.1 ppm cobalt as a safety factor, even when adequate amounts of the vitamin are added. It is usually included as cobalt iodized salt.

Manganese Manganese deficiency can cause poor reproductive performance, irregular estrus and weak, newborn pigs that show a poor sense of balance. It can also adversely affect growth, feed efficiency and fat deposition in growing-finishing pigs.

Manganese is normally found in adequate amounts in common feedstuffs, so supplemental sources are not needed.

Fluorine No specific requirement for fluorine has been determined for swine. Excessive fluorine in the diet is toxic and should not exceed 0.014 per cent of the total ration.

Sulfur Sulfur is present in the diet as the amino acids methionine and cystine, and as free sulphur containing salts. Supplemental sulfur is not generally required.

Potassium, magnesium Both calcium and these minerals are expected in feedstuffs. Feed ingredients contain adequate potassium and magnesium for swine.

Mineral sources

Calcium and phosphorus Both calcium and phosphorus are available from meat and bone meal, skim milk and milk products. Plant proteins and cereal grains are very poor sources of calcium. Not all the phosphorus provided by plant proteins and cereal grains is readily available to the animal. Legumes and pasture provide some calcium.

Mineral supplements which supply calcium and phosphorus are steamed bone meal, dicalcium phosphate and deflourinated rock phosphate. Other sources, such as feed rock phosphate, phosphorized limestone, colloidal phosphate, and superphosphate, ***must*** be avoided since these contain dangerous levels of fluorine. High phosphorus fertilizers should not be used because of possible contamination.

For calcium only, feed-grade limestone (38 per cent) or oyster shell is usually best. Dolomitic limestone, marl, wood ashes and gypsum have lower calcium levels, but are still satisfactory.

Salt Cobalt-iodized salt, or trace mineralized salt are the preferred sources.

Trace minerals Trace minerals are needed in very small amounts in the ration. Facilities required for weighing or properly mixing these minerals are quite sophisticated and few producers can justify their purchase. Only a few grams of these trace minerals are needed in a tonne of feed. Therefore, accurate weighing and precise mixing is essential.

Purchase of a trace mineral premix is the simplest method of providing trace minerals if you are mixing grain, a protein feed (soybean meal or canola meal) and a mineral-vitamin premix. Usually, trace minerals are added to commercial protein supplements at adequate levels. If not, and the volume of supplement purchased is large enough, specific minerals may be added to the supplement on a custom basis.

There is no basis for feeding a mineral supplement free-choice to swine as long as adequate levels of calcium, phosphorus, salt and trace minerals (iron, zinc, iodine, selenium) are included in the ration.

Vitamins

Although vitamins are required in small amounts, they serve essential functions in maintaining normal growth and reproduction. Few vitamins can be synthesized by the pig in sufficient amounts to meet its needs. Some are found in adequate amounts in the feedstuffs commonly used in swine rations; others must be supplemented. Although the total amount of a vitamin may be adequate for maximum performance, some vitamins are present in bound or unavailable forms in common feedstuffs. Supplementation with these vitamins is essential. In total confinement, vitamin requirements are even more critical because alternate and incidental sources have been removed (soil and pasture).

Vitamins are organic compounds which differ from each other in both structure and function. They are classified into two groups, fat-soluble and water-soluble.

Fat-soluble vitamins

— Vitamin A
— Vitamin D
— Vitamin E
— Vitamin K

Water-soluble vitamins

— Thiamine
— Riboflavin
— Niacin
— Pantothenic Acid
— B_6
— Choline
— Myo-Inositol
— Biotin
— P-amino benzoic acid
— B_{12}
— Vitamin C

Essential vitamins to be added to swine rations

The primary fat-soluble vitamins of concern are Vitamins A, D and E, and Vitamin K under some circumstances. Riboflavin, niacin, pantothenic acid and Vitamin B_{12} are the water-soluble vitamins most likely to be deficient in the ration. Choline is also frequently added to practical swine diets. The body can keep reserves of the fat-soluble vitamins stored for a considerable length of time. Stores of the water-soluble vitamins are depleted quite rapidly.

Vitamin A Retinol, retinal, and retinoic acid are forms of Vitamin A. This vitamin is essential in many body functions, particularly vision and reproduction. The adult pig can store large amounts of this vitamin in its body. The newborn pig must obtain most of its Vitamin A requirements from colostrum and milk, since it possesses only a limited store at birth.

Vitamin A needs can be met naturally (example cod liver oil) or in synthetic form. Naturally occurring precursors of Vitamin A are found in leafy green vegetables and forages such as alfalfa. The common

form of the precursor is carotene. Carotene can be converted into Vitamin A in the intestinal wall of the pig. It is present in considerable quantities in pasture, alfalfa hay or meal, and yellow corn. Carotene and Vitamin A are rapidly destroyed by exposure to air, light, and rancidity (a result of high temperature). It is difficult to assess the amount present in feed. Swine rations should be supplemented with a stabilized, synthetic form of the vitamin.

Deficiency symptoms in growing pigs are unthrifty appearance, poor coordination and various eye abnormalities. Sows failing to breed or which produce dead, weak or deformed piglets, should be suspect. Vitamin A deficiency in boars results in sterility.

Vitamin D Vitamin D, the sunshine vitamin, plays a vital role in the absorption of calcium and phosphorus, and the formation of bone. The requirement for Vitamin D depends on the quantities of calcium and phosphorus present and the calcium: phosphorus ratio. Supplying Vitamin D in excess will not make up for a deficiency of the two minerals.

The natural source of Vitamin D for newborn pigs is sow's milk. Pigs that have access to sunlight will produce Vitamin D. This results from the action of sunlight on a precursor found in the skin. Most feedstuffs, except for sun-cured hays, are low in this vitamin. Thus, pigs in total confinement require supplemental Vitamin D.

Deficiency symptoms in young pigs include rickets, stiffness, enlargement of joints, and loss of appetite. In older pigs, the bones tend to fracture more easily, and sows give birth to dead or weak piglets.

Vitamin E Vitamin E is required for normal reproduction and growth. The function of Vitamin E is closely related to that of selenium. Both are involved in maintaining cell wall structure (membrane integrity).

Vitamin E deficiency may cause nutritional muscular dystrophy, mulberry heart disease, hepatosis dietetica, and a brownish-yellow discoloration of fat tissue. Although these symtoms are similar to selenium deficiency, there is not a total substitution of selenium for the Vitamin E required. Both nutrients are required in the pig's diet.

B-Vitamins

Riboflavin (B_2) Since cereal grains and plant proteins are poor sources, deficiencies of this vitamin would be common without supplementation. Deficiency symptoms in growing pigs are loss of appetite, rough hair, vomiting, inability to stand normally, and slow growth rate. In sows, symptoms are poor conception rates and the birth of weak or dead pigs.

Niacin Most cereal grains contain adequate levels of niacin, but it exists mainly in a bound form which is unavailable to the pig. Deficiency is characterized by a rough skin condition and diarrhea. Ulcers may occur in the mouth. A niacin deficiency may give rise to Necrotic Enteritis, but this condition is more likely the result of other causes.

Pantothenic Acid Again, cereal grains and plant proteins are a poor source of this B-Vitamin. A deficiency can result in an uncoordinated gait (commonly referred as "goose-stepping"), as well as diarrhea and poor growth rate.

Vitamin B_{12} Plant products are poor sources of this vitamin. Animal products are good sources. Deficiency symptoms are reduced growth rate and anemia.

Other important vitamins

Vitamin K Vitamin K is referred to as the coagulation or antihemorrhagic vitamin. If deficient, hemorrhaging occurs from the naval at birth, and following castration. In some cases, it occurs without causing death. Supplementation of the sow feed with Vitamin K seems to correct the problem and is common under today's confinement conditions.

Choline Most feed companies supplement diets with choline on a regular basis. Choline has been found to prevent spraddle legs in baby pigs fed purified diets. Under practical conditions, other factors may be involved in the spraddle leg condition, and no response may be obtained to choline supplementation.

Biotin The role of biotin, especially supplemental biotin, in swine nutrition is not well understood. The main sources of biotin to the pig are feedstuffs, augmented by microbial syntheses in the digestive system. Recent field reports strongly suggest that these sources may not always be adequate to maintain optimal hoof integrity and reproductive function of totally-confined breeding stock.

However, results from some research has failed to show a difference between supplemented and unsupplemented diets. Until further research studies are conducted, biotin supplementation in pig diets will be questionable and based largely on speculation. Clinical signs which may be associated with a biotin deficiency are dermatitis, cracking of soles and hooves, spastic paralysis of the hind legs, decreased rate of gain and poor reproductive preformance.

Deficiencies of vitamins

Under farm conditions, single vitamin deficiencies are unusual. In most cases, a multiple vitamin deficiency will exist. In other words, the deficiency symptoms may be a combination of symptoms

described for single vitamins. Borderline deficiencies of any vitamin are difficult to detect and may cost the swine producer considerable money. Get advice if you suspect a problem.

Vitamin sources

Cod liver oil, green plants and sun-cured hays are good sources of Vitamin A, D and E. Exposure to sunlight produces Vitamin D.

Synthetic forms of Vitamins A, D and E, as well as the necessary B-vitamins, are available, and are relatively inexpensive. Commercial protein supplements or specific vitamin and/or mineral-vitamin premixes should be formulated to supply required levels of the vitamins most often lacking. Most vitamins are supplied in synthetic form. These synthetic forms are quite stable and maintain their potency.

Water

Water is the most essential, but most often neglected, nutrient. Pigs can exist longer with other nutrients lacking than when water is absent or insufficient. ***Pigs need plenty of clean fresh water at all times.*** Performance by all types of pigs is restricted by water shortage. Milk production, rate of gain and amount of feed consumed by pigs are adversely affected by water restriction.

Importance of water quality

The following table indicates the relative quality of water based on total solids content. (Table 8).

TABLE 8. ASSESSMENT OF WATER QUALITY

Total Solids Content of Water (ppm)	Quality
0-999	Exellent
1,000 - 3,999	Good
4,000 - 6,999	Satisfactory
7,000 and over	Unsatisfactory

Water containing up to 7,000 ppm total solids is acceptable for growing and finishing pigs. Some concern has been expressed when using high total solid content water for lactating sows and nursing or early-weaned pigs. With this in mind, 5,000 ppm has been set as the limit for these classes of pigs.

Adaption to a high saline water may take a few days. Good management dictates that changes in water supply should be monitored closely. This is particularly important for young pigs.

Downward adjustments in salt added to the ration can be made to account for the sodium and chloride ions present in the water.

Algae growth in ponds or dugouts can give the water an offensive odor and taste. Certain types of blue-green algae are highly toxic and can cause death.

Two problem salts

Nitrates Nitrates in livestock water are often an indication of bacterial contamination. Bacterial contamination of the water supply can cause problems with pigs. Conversion of nitrate to nitrite by bacteria can have adverse effects on the pig, causing formation of methemoglobin, a form of hemoglobin with reduced oxygen carrying capacity.

Sulphates Sulphates in large quantities in livestock water can create problems. The pigs may have mild diarrhea, but performance is usually not affected.

NOTE: Information on testing and water analysis is available from:

The Technical Services Laboratory
Department of Environment & Workplace, Safety & Health
745 Logan Avenue
Winnipeg, Manitoba
R3E 1M8
Phone 945-4193

The Manitoba Agriculture factsheet *Livestock Water Quality*, Agdex 716-13 provides complete information.

Under normal conditions, swine will consume 2.0 to 4.0 kg of water per kilogram of dry feed, depending on stage of growth or reproduction. Table 9 indicates daily water requirements of the different weight classes of pigs.

TABLE 9. DAILY WATER REQUIREMENTS OF PIGS

Body Weight (kg)	Litres/Day
14	2.3
18 - 32	2.7
32 - 57	7.7
57 - 100	9.0 - 11.4
Pregnant Sows	13.6 - 16.8
Lactating Sows	18.2 - 22.7

The most important consideration with pigs is to ensure that there is an adequate supply of fresh, uncontaminated water available at all times.

Feed additives

Feed additives are those agents or drugs included in animal rations that do not supply nutrients to the animal.

Over the past 30 years, feed additives have been used to improve growth rate, feed efficiency, and to control disease. Those currently in use are listed in Table 10 according to amount used, approved use and restrictions involved.

Categories of feed additives

Antibiotics Antibiotics are substances produced by micro-organisms which kill or inhibit the growth

of other micro-organisms. An example of a commonly used antibiotic is penicillin.

Antibacterial agents Antibacterial agents are synthetic substances which kill or inhibit the growth of micro-organisms. Chemicals such as arsanilic acid and nitrofurozone act in this manner. By their action these chemicals permit animals, presumably depressed in growth rate and feed efficiency by the presence of intestinal bacteria, to grow to their normal potential.

Growth Promotants Growth promotants are substances which improve growth rate or feed efficiency through systemic action, or the hormonal, biochemical or metabolic processes of the pig.

Production Improvers Production improvers are any agents that improve animal performance. These are used for special purposes. Feed additives may be used to improve the flavor or sweeten the feed to improve intake, and therefore efficiency. Wormers included in the feed could be classified here, since by reducing the parasite load, the pig makes better use of its feed.

Response to feed additives

The major benefit of antibiotic feed additives is to improve general animal health. Younger animals respond best to feed additives, with the positive response decreasing as age and weight increase. Survival rates in young pigs are greater when feed additives are used. Feed conversion efficiency and average daily gain can be increased by about 5 per cent or higher.

NOTE: *To produce the desired affect, additives, particularly antibiotics, must be used at the proper levels and at the proper time.*

One of the major disadvantages of feed additives is cost. Improvement in growth or health *must* cover the additional cost of rations. Perhaps changes in management or changes in the quality of stock would be a less expensive means to achieve the same result.

Continuous use of the same antibiotic may lower its overall effectiveness. Periodic changes or deletion of a particular drug may be necessary. This is best done when changes in the ration occur, such as changing from a starter to a grower ration.

NOTE: *Some additives have precautions or restrictions which must be adhered to by the producer. It is the responsibility of the swine producer to observe and comply with the recommendations for the use of each feed additive and the respective withdrawal period. When unsure about the use of additives, consult someone knowledgeable about this subject (veterinarian, regional swine specialist, swine nutritionist).*

Guidelines on the use of additives can change and the producer should always be aware of the most recent recommendations and regulations. The following table should be considered only as a general guide. Before using any additive, consult the *'Compendium of Medication Ingredient Brochure (MIB)'*, available from the Plant Products Division, Agriculture Canada - Winnipeg phone 949-2236.

TABLE 10 SOME CURRENT FEED ADDITIVES: LEVELS, USAGE AND RESTRICTIONS

Name of Additive	Amount in the Feed	Approved Use	Restrictions
Arsanilic acid	50 to 99 g/tonne feed as sole ration.	For starters, growers and finishers.	Withdraw 5 days before slaughter. No other arsenicals are to be fed.
3-nitro-4 hydroxyphenylarsonic acid.	25 to 50 g/tonne feed as sole ration	For starter, grower and finisher diets.	Withdraw 5 days before slaughter. No other arsenicals are to be fed.
"Aureomycin"	220 g/tonne	Fed in prestarter feeds to pigs up to 6 weeks of age for treatment of bacterial scours.	7 day withdrawal period on all levels except growth promotion (5.5 g/tonne)
	110 g/tonne	Aids in treatment of bacterial scours. Maintains weight gains and appetite during periods of stress.	Feed until 3 days after scour symptoms disappear. Feed until 10 days after stress condition is eliminated.

(Table 10 . . . continued)

Name of Additive	Amount in the Feed	Approved Use	Restrictions
"Aureomycin" (continued)	55 g/tonne	Prevention of bacterial scours in early growth up to 27-32 kg. Maintain weight gains in presence of atrophic rhinitis.	No effect on organism causing atrophic rhinitis.
	5.5 g/tonne	Growth promotion in starter, grower and finisher diets.	
"Aureo SP 250"	275 g/tonne	Prestarter and starter feeds only, except on veterinary prescription. Maintain weight gains plus feed efficiency in presence of atrophic rhinitis and stress. Treatment of bacterial scours in all classes of swine.	Feed until 10 days after stress condition is eliminated. No effect on the organisms causing atrophic rhinitis. Discontinue use 10 days before slaughter.
"Banminth II" (morantel tartrate)	1.25 g/kg. Feed as sole ration at rate of 1 kg/100 kg body weight. When this amount is consumed, resume normal feeding.	For removal and control of stomach worms, mature and immature large roundworms and nodular worms in all pigs.	Treated animals must not be slaughtered for food until 30 days after last treatment.
"Emtryl" Dimetridazole	150 mg/kg of complete feed. Feed as sole ration.	For the prevention of swine dysentry in feeder pigs.	Feed to swine intended for slaughter. Discontinue use 5 days before slaughter.
"Hygromix" Hygromycin B	13.2 mg/kg of complete feed.	Control of large roundworm and nodular worms. Use in starter-grower feeds up to 45 kg or treatment as sole ration for 5 weeks. Sow may be fed 2.3 kg per day for 8 weeks prior to farrowing.	Discontinue use 2 days before slaughter.
"L-S 20 Premix" Lincomycin Spectinomycin	44 g/tonne	For the prevention of swine dysentry in growing swine up to 57 kg.	Swine must not be slaughtered for a least 24 hours after last treatment. Feed to swine intended for slaughter.
"Mecadox" Carbadox	55 mg/kg of complete feed. Feed as sole ration up to 35 kg.	Aids in improving weight gains and feed efficiency during periods of stress and in the presence of atrophic rhinitis. Aids in prevention and control of vibrionic dysentry.	Feed only to slaughter pigs and discontinue use at least 35 days before slaughter. This product does not have any effect on the organisms causing atrophic rhinitis.

(Table 10 . . . continued)

Name of Additive	Amount in the Feed	Approved Use	Restrictions
"Nf-180" Furazolidone	330 mg/kg of complete feed. Feed as sole ration for 10-14 days.	For treatment of bacterial enteritis and bloody dysentry.	Discontinue use at least 5 days before slaughter.
"NFZ" Nitrofurazone	550 mg/kg of complete feed. Feed as sole ration for 7 days.	Treatment of infectious nectrotic enteritis.	Not effective for treatment of bloody scours. Discontinue use at least 5 days before slaughter.
Oleandomycin	5.5 g/tonne	Growth promotion in starter, grower and finisher feeds.	
Piperazine	2957 mg/kg of complete feed. Feed as sole ration for 24 hour period.	Removal of large roundworms and nodular worms from all pigs.	
"Protamone" (Thyroactive iodinated casein)	220 g/tonne. Feed sows 3 days before farrowing and until pigs are weaned.	Aids in stimulating milk production in nursing sows.	Do not feed to other pigs and especially not to dry sows.
"Pro-Strep" (Procaine penicillin, streptomycin)	55 g/tonne procaine penicillin and 165 g/tonne streptomycin.	Aids in treatment of bacterial enteritis in pre-starters fed up to 6 weeks of age.	
	27.5 g/tonne procaine penicillin and 82.5 g/tonne streptomycin.	Aids in treatment of bacterial scours.	
	27.5 g/tonne	Growth promotion in starter, grower and finisher diets.	
Pyrantel Tartrate	106g/tonne. Feed as sole ration for 5-7 weeks.	For the prevention of large roundworms.	Feed only to swine intended for slaughter. Withdraw at least 7 days before slaughter.
"Ridzol" ronidazole	60 mg/kg of complete feed.	As an aid in the prevention of swine dysentry.	Do not feed to breeding animals or swine intended for breeding purposes. Discontinue feeding at least 3 days before slaughter.
"Terramycin" (oxytetracycline hydrochloride)	550 g/tonne. Feed to sows for 2 week period.	Aids in reducing abortion caused by leptospirosis.	NOTE: 7 days withdrawal proposed on all levels except growth promotion (5.5 g/tonne).
	110 g/tonne of complete feed.	Treats bacterial scours and appetite during periods of stress.	Feed until 3 days after symptoms disappear. Feed until 10 days after stress is eliminated.

(Table 10 . . . continued)

Name of Additive	Amount in the Feed	Approved Use	Restrictions
"Terramycin" (oxytetracycline hydrochloride) (continued)	220 g/tonne of complete food.	Fed to pre-starters up to 6 weeks old for prevention and treatment of bacterial scours.	
	55 g/tonne.	Maintain gain in the presence of atrophic rhinitis. Prevention of bacterial scours in early growth up to 27-32 kg.	No effect on organisms causing atrophic rhinitis.
	5.5 g/tonne.	Growth promotion in starter, grower and finisher feeds.	
"Tramisole" (Levamisole)	0.8g/kg of complete feed. Feed as sole ration at a rate of 1 kg/100 kg body weight.	Aid in the treatment of swine infected with roundworms, lungworms, nodular worms, stomach worms and intestinal threadworms.	Treated animals must not be slaughtered for food until 4 days after last treatment.
"Tylan-10" (Tylosin phosphate)	1 g of tylosin tartrate per 3.8 litres of drinking water for 3 days followed by 110g/tonne in complete feed for 3 weeks.	Treatment of vibrionic dysentry.	Pigs under treatment must not be slaughtered for meat. Discontinue use 48 hours before slaughter.
	44 g/tonne.	For pigs up to market weight. Aid in prevention of recurrence following treatment for vibrionic dysentry.	
	44 g/tonne starter, 22 g/tonne grower, 11 g/tonne finisher.	Growth promotion in starter, grower and finisher feeds.	No withdrawal on growth promotion levels.
"TN 200" (Oxytetracycline hydrochloride and furazolidone)	110 g/tonne of oxytetracycline hydrochloride and 110 g/tonne of furazolidone in the complete feed.	Prevention (feed continously) and treatment (10-14 days) for necrotic enteritis.	Not acceptable for pre-starter feeds. Discontinue use at least 7 days before slaughter.
"Tylarone" Tylosin Phosphate & Furazolidone	44 g/tonne of tylosin phospate, 220 g/tonne of furazolidone.	An aid in prevention of bacterial enteritis in starter pigs associated with swine dysentry. Feed as sole ration for 21 days.	Withdraw 5 days before slaughter. For use in starter feeds only.
"Stafac" Virginiamycin	110 mg/kg of feed for 2 weeks followed by 55 mg/kg of feed for 4 weeks.	For the treatment and control of swine dysentry.	Not to be fed to swine intended for breeding purposes.

(Table 10 . . . continued)

Name of Additive	Amount in the Feed	Approved Use	Restrictions
"Stafac" Virginiamycin (continued)	11 g/tonne	Growth promotion in starter, grower and finisher feeds.	
Zinc Bacitracin or Bacitracin methylene disalicylate	55 g/tonne.	Aids in prevention of bacterial scours.	Does not affect coliform diarrhoea.
	110 g/tonne. Feed as ration for 5-15 days.	Aids in treatment of bacterial scours.	
	4.4 g/tonne.	Growth promotion in starter, grower and finisher diets.	
Zinc Bacitracin, Procaine Penicillin	55 g/tonne.	Aids in prevention of bacterial scours.	
	110 g/tonne. Feed as sole ration for 5-15 days.	Aids in treatment of bacterial scours.	

SOURCE: Compendium of Medication Ingredient Brochures (MIB), Plant Products Division, Agriculture Canada.

NOTE: Two or more drugs cannot be used in the same feed, unless the combination is specifically cleared in MIB.

Use of sulfa drugs in hog feeds

Sulfa drugs available in registered feeds as Aureo-SP250 or Chlorachel 250/swine, or on veterinary prescription as sulfamethazine, are valuable production aids. Their role in preventing and treating diseases has been well documented since the early 1950's when sulfonamides were first added extensively to swine rations.

However, sulfa residues in meat (pork) may cause allergic reactions or induce drug resistance in humans. To insure that Canadian pork for domestic consumption or export is free from sulfa residue, a federal regulation was approved in 1979 prohibiting the addition of sulfa drugs in grower or finisher swine rations except on veterinary prescription. In effect, all hogs should be free of sulfa additives for about 80 days prior to market and slaughter.

At the same time the Federal Government began a surveillance program for sulfa residues in hog carcasses. Whenever a violative sample is found, Federal Plant Products Inspectors visit the producer's premises and submit a detailed report on his overall operation — with specific emphasis on probable causes of the sulfa contamination. This is done in an effort to assist the producer to eliminate the problem in any future shipments.

The producer must then submit a test shipment of five hogs for further testing. These carcasses are held frozen, pending results (2-3 weeks). If sulfa residues are over 0.1 ppm, carcasses are deemed unfit for human consumption and are settled on a 'nil value' basis. Producers must withhold hogs from the market until the problem has been solved. The very significant potential losses are obvious.

The possible causes of sulfa residues higher than the allowable 0.1 ppm are numerous, but essentially can be narrowed down to two reasons:

- Inadequate withdrawal time, or
- Consumption of low level sulfa up to the time of slaughter.

Field investigations of U.S. premises where the owners have marketed hogs with violative tissue residues indicated 92 per cent of producers followed proper withdrawal times. Most of the violations were the result of accidental low level contamination of rations and water during the withdrawal period. Consider the following:

Researchers have found that as little as one quarter teaspoon of sulfamethazine in a tonne of feed is enough to cause tissue violations.

Eighteen kg of medicated feed (110 grams of sulfamethazine per tonne) will contaminate a tonne of clean feed and cause the muscle of hogs fed this feed to have over 0.1 ppm of sulfa present.

Usually 32 to 45 kg of feed is left in the bottom of bulk bins, grinder-mixers, etc.

The drug carryover in water lines from medicated water has been reported up to 2½ months.

Sulfa-free pigs placed in pens containing manure from pigs fed sulfonamides have violative tissue residues in 48 hours.

The following procedures should be observed by producers:

- Flush all feed-handling equipment with non-medicated feed after handling medicated feeds. This will prevent cross-contamination or carryover of medicated feed to a feed ration that must not contain sulfa drugs.
- Clean pens or move hogs to a clean pen 48 hours after the removal of medicated feed. This will prevent contamination of feces, urine and bedding material.
- Never use a common storage bin for medicated and non-medicated feeds.
- Know and observe all recommendations concerning withdrawal times for medicated feeds.
- Insist that medicated feeds are properly labelled when purchased and report any violation to Agriculture Canada officials.

If you mix your own feed follow the additional precautions:

- Weigh all drugs to be added to the feed mix.
- Mix all sulfa-medicated feeds at one time. Follow this mix by preparing a grower ration and end with mixing a finishing feed. In this way, some of the residues of high concentrations of sulfa used in the starter diet are flushed through into the grower ration but the finishing ration should be sulfa-free. However, flushing must still be carried out before the non-medicated feed is prepared with the same equipment.

It is recommended that a representative, one-pound sample of all finishing feeds be saved for about four months. Also record dates, ingredients, sequence of mixes, batch volumes, medication levels and delivery location. If problems occur with residues, these records can be checked.

Nutrient requirement tables

Table 11 is adapted from the National Academy of Sciences — National Research Council Publication — Nutrient Requirements of Swine (1979). The "A" portion of Table 11 lists nutrient requirements per kilogram or as a percentage of feed eaten. The "B" portion lists nutrient requirements on a daily basis. Part "A" assumes a certain daily feed intake, and especially for breeding stock actual feed intake can vary from the figures given. If intake is below that listed, increase all nutrient concentrates to meet the daily requirements of Table 11, part "B". If feed intake is greater than that listed, nutrient concentration in the ration may be lowered to meet the daily nutrient requirement. Remember, pigs eat to

TABLE 11 SOME SWINE NUTRIENT REQUIREMENTS
(Except Vitamins and some Minerals*)

Type of Diet	Starting		Growing		Finishing	Breeding Stock		
Pig Weight, kg.	5-10	10-20	20-35	35-60	60-100	110-250	140-250	110-250
Expected gain, kg/day	0.30	0.50	0.60	0.75	0.80	Bred	Nursing	Boar
Expected intake, kg/day	0.50	1.00	1.50	2.00	3.00	1.8	5.5	2.3
A. Requirement as percentage of ration								
Digestible Energy (DE) Kcal/kg	3500	3370	3380	3390	3395	3400	3395	3400
Crude protein (%)	20	18	16	14	13	12	13	12
Lysine (%)	0.95	0.79	0.70	0.61	0.57	0.43	0.58	0.43
Methionine & cystine (%)	0.56	0.51	0.45	0.40	0.30	0.23	0.36	0.23
Calcium (%)	0.80	0.65	0.60	0.55	0.50	0.75	0.75	0.75
Phosphorus (%)	0.60	0.55	0.50	0.45	0.40	0.60	0.50	0.60
B. Daily Nutrient Needs								
Digestible Energy (Kcal)	1750	3370	5055	6740	10110	6120	18673	7820
Crude protein, g.	100	180	240	280	390	216	715	276
Lysine, g.	4.8	7.9	10.5	12.2	17.1	7.7	31.9	9.9
Methionine & cystine, g.	2.8	5.1	6.8	8.0	9.0	4.1	19.8	5.3
Calcium, g.	4.0	6.5	9.0	11.0	15.0	13.5	41.2	17.3
Phosphorus, g.	3.0	5.5	7.5	9.0	12.0	10.8	27.5	13.8

*Pigs also have requirements for: Vitamins A, D, E, and K, niacin, riboflavin, pantothenic acid, vitamin B_{12}; the trace minerals — managanese, iron, copper, zinc, magnesium, selenium, cobalt, iodine; and 0.25% to 0.5% salt (sodium chloride) added to all swine rations for sodium and chlorine needs.

meet their energy requirements, therefore, rations should be adjusted accordingly.

The daily nutrient requirements for pigs must be met regardless of the amount fed. The percentage requirements given are valid only if the listed amount of feed is eaten daily.

NOTE: *These requirements were formulated for moderate climates. Pigs housed in cold climates (ouside in non-heated shelters) need about 25 per cent more energy. In particular, it is recommended that a 14 per cent crude protein diet is the minimum for breeding stock.*

Remember, the NRC requirements are minimum requirements.

Ration formulation

Once the nutrient requirements of the various classes of swine are identified, it is necessary to supply feedstuffs in the right proportions to meet nutrient requirements.

All nutrients must be present

All nutrients are needed in adequate levels. Table 12 illustrates the need for all nutrients. When some are deficient, less than ideal performance is obtained. A summary of clinical signs (outward appearance) and sub-clinical signs (determinable only by laboratory methods) of nutrient deficiencies are given in Table 13. Pigs fed with all nutrients grow much faster and more efficiently.

TABLE 12. EFFECTS OF DEFICIENCIES OF MAJOR NUTRIENTS ON PIG PERFORMANCE (GROWING PIGS)

	Rations Fed		
	Grain Alone	Grain + Vitamins + Minerals	Grain + Protein + Mineral + Vitamins
Average daily gain (kg/day)	0.32	0.41	0.59
Average daily feed (kg/day)	1.65	1.98	2.16
Feed/Unit gain (feed efficiency)	5.3	4.7	3.7

(University of Alberta)

TABLE 13 SIGNS OF NUTRIENT DEFICIENCIES IN SWINE*

Nutrient	Signs of Nutrient Deficiency	
	Clinical	Subclinical
Energy	Weakness, low body temperature, loss of weight, coma, and death	Hypoglycemia Loss of subcutaneous fat Elevated hematocrit and serum cholesterol Reduced blood glucose, calcium, and sodium
Protein: Amino acid	Impaired growth Unthriftiness Reduced resistance to bacterial infection	Kwashiorkor-like signs in baby pigs, including reduced serum protein and serum albumin, anemia, gross edema, and increased lipid liver concentration
Fat: Linoleic acid	Scaly dermatitis may appear	Small gallbladder Elevated triene/tetraene in tissue lipids
Vitamin A	Incoordination Lordosis Paralysis of rear limbs Night blindness Congenital defects	Retarded bone growth Increase in cerebrospinal fluid pressure Degeneration of sciatic and femoral nerves Minimal visual purple Atrophy of epithelial layers of genital tract
Vitamin D	Rickets Osteomalacia Low calcium tetany	Lack of bone calcification and proliferation of epiphyseal cartilage Rib and vertebra fracture Low plasma calcium, magnesium, and inorganic phosphorus levels Elevated serum alkaline phosphatase levels

Table 13 Continued

Nutrient	Signs of Nutrient Deficiency	
	Clinical	Subclinical
Vitamin E-Selenium	Edema Sudden death	Generalized edema Liver necrosis (hepatosis dietetica) Microangiopathy Cardiac muscle degeneration (mulberry heart) Pale, dystrophic muscle
Vitamin K	Pale newborn pigs with loss of blood from umbilical cord Sudden death following dicoumarin intake	Increased prothrombin time Increased blood-clotting time Internal hemorrhage Anemia due to blood loss
Thiamin	Poor appetite Poor growth Sudden death	Cardiac hypertrophy Bradycardia First and second degree auriculoventricular block Elevated plasma pyruvate
Riboflavin	Slow growth Seborrhea Impaired sow reproductivity	Lens cataracts Increase in neutrophilic leukocytes Birth of weak pigs with skeletal anomalies
Niacin	Poor appetite Poor growth Severe diarrhea Dermatitis	Necrotic lesions of intestine
Pantothenic acid	Poor appetite Poor growth Diarrhea Unusual gait (goose-stepping) Impaired sow reproductivity	Inflammation of colon Degeneration of sciatic and peripheral nerves Reduced blood pantothenic acid level Reduced free pantothenic acid level in milk
Vitamin B_6	Poor growth Epileptic seizures	Microcytic hypochromic anemia Elevated serum iron Fatty infiltration of liver Elevated urinary xanthurenic acid Elevated gamma globulin-like blood protein fraction
Vitamin B_{12}	Depressed growth Hypersensitivity Reduced sow reproductivity	Reduced serum and tissue B_{12} levels
Choline	Slow growth Reduced litter size	Fatty infiltration of liver Reduced conception rate
Biotin	Dermatosis Spasticity of hind legs	Reduced urinary biotin excretion
Folacin	Poor growth Weakness	Normocytic anemia
Calcium	Rickets Osteomalacia Low calcium tetany	Lack of bone calcification Bones easily fractured Low plasma calcium level Elevated serum inorganic phosphorus and alkaline phosphatase

Table 13 Continued

Nutrient	Signs of Nutrient Deficiency	
	Clinical	Subclinical
Phosphorus	Poor growth Rickets Osteomalacia	Lack of bone calification Bones easily fractured Low serum inorganic phosphorus level Elevated serum calcium and alkaline phosphatase Enlarged costochondral junction (beading)
Magnesium	Poor growth Stepping syndrome Weakened carpo-metacarpo-phalangeal and tarso-metatarso-phalangeal joints Tetany	Low serum magnesium and calcium Reduced bone magnesium
Potassium	Anorexia Rough hair coat Emaciation Ataxia	Reduced heart rate Increased PR, QRS, and QT intervals on electrocardiogram Reduced serum potassium
Sodium	Poor appetite Low water consumption Unthriftiness	Negative sodium balance Elevated serum potassium Elevated plasma urea nitrogen Reduced chlorine retention
Chlorine	Poor growth	Reduced plasma chlorine Reduced sodium and potassium retention
Iron	Poor growth Rough hair coat Pallor Anoxia	Hypochromic microcytic anemia Enlarged heart and spleen Enlarged fatty liver Ascites Clumping of erythroblastic cells in bone marrow Reduced serum iron and percent transferrin saturation
Copper	Leg weakness Ataxia	Microcytic hypochromic anemia Reduced serum copper and ceruloplasmin Aortic rupture Cardiac hypertrophy
Zinc	Poor growth Poor appetite Parakeratosis	Reduced serum, tissue, and milk zinc Reduced serum albumin-globulin ratio Reduced serum alkaline phosphatase Reduced thymus weight Retarded testicular development Impaired reproductivity of sows
Iodine	Goiter Myxedema Sows farrow weak, hairless pigs	Enlarged hemorrhagic thyroid Hyperplasia of follicular epithelium of thyroid Reduced plasma protein-bound iodine
Manganese	Lameness in growing pigs Increased fat deposition in pregnant gilts with birth of weak pigs with poor sense of balance	Replacement of cancellous bone with fibrous tissue Early closure of distal epiphyseal plate Low serum manganese and alkaline phosphatase Negative manganese balance

Table 13 Continued

Nutrient	Signs of Nutrient Deficiency	
	Clinical	Subclinical
Water	Poor appetite Dehydration Loss of body weight Possible salt poisoning Death	Elevated hematocrit Elevated plasma electrolytes Loss of temperature regulation Tissue dehydration

*Source: National Academy of Sciences — National Research Council Publication "Nutrient Requirement of Swine 1979".

Proper levels of all nutrients are needed

If less than the recommended level of supplement is added, reduced performance will result. The influence of proper supplementation is shown in Table 14. Pigs 20 to 90 kg not receiving proper levels of supplement grew poorly. The best level of performance occurred when pigs received 150 kilograms of supplement per tonne.

The nutrient requirements of swine as outlined in Table 11 are guidelines. The requirements listed assume the presence of good housing conditions, good management and healthy animals.

Methods of providing balanced rations

There are essentially four methods of providing balanced rations to pigs:

- Buy a complete ration from a feed company and save the time that proper mixing requires. There will be a charge for this service which is provided by the feed mill.
- Buy a commercial feed supplement (example, a supplement which contains protein, minerals and vitamins) and mix this with available grains.
- Buy a protein meal (example, soybean meal, fish meal) or use a home-grown protein supplement such as fababeans with a commercial mineral-vitamin premix and grains.
- Buy individual protein, mineral and vitamin feedstuffs and mix with grains.

The first method usually assures a nutritionally balanced diet. This responsibility falls on the feed company, and a premium is paid for the service. However, the producer has little or no control (unless a custom mix is requested) over the ingredients being used in the feed batch. Large commercial feed mills operate on a least, or low cost basis. Thus, proportions of ingredients in feeds can change depending upon their prices. Changes in ingredients can affect the growth rate of pigs. If growth rate is reduced, the bottom line is whether a better dollar return per pig or greater barn throughput is most desirable.

The other methods involve the selection of feed ingredients, and various levels of on farm mixing. Mixing home-grown grains with a ready made supplement is fairly straight forward. When adding mineral and vitamin premixes, or individual minerals and vitamins, extra care is required to ensure adequate mixing, so that the pigs receive a balanced ration.

Choosing a method Selection of a feed purchase program depends on priorities and resources. If using home-grown grains, consider buying supplemental protein and mixing your own rations. If

TABLE 14. PERFORMANCE OF GROWING-FINISHING PIGS RECEIVING DIFFERENT LEVELS OF SUPPLEMENT

	Level of Supplement per Tonne			
	kg/tonne			
	0	25	100	150
Average daily gain (kg/day)	0.25	0.27	0.43	0.71
Feed/Gain	5.09	4.70	3.68	2.88
Days on experiment	*	275	176	106

*Some pigs stopped growing and did not reach market weight.

(F.X. Aherne, University of Alberta)

buying grain, it may pay to purchase a complete feed rather than grain and supplements, then having to mix them yourself. If time would be best used in some other aspect of your operation, other than feed mixing, your choice may be the purchase of a complete feed, or a system requiring a minimum of mixing. Since feed accounts for such a high per cent of costs, possibly efforts placed in the area of feed mixing would return more on your investment. *The choice is an individual one, and is particular to your operation.*

Feed ingredients

Many ingredients are available for feeding to pigs. One ingredient cannot supply all the necessary nutrients in the correct proportions and amounts. Feedstuffs must be combined to provide a balanced diet. A producer should select his feed ingredients carefully.

Factors to consider when purchasing feedstuffs

Cost Several feed ingredients may supply the nutrients required. Ingredients are usually priced differently. These prices can fluctuate daily, monthly or seasonally. It is important that a producer be aware of price fluctuations to enable economical purchasing. The actual cost per kilogram of feedstuff is not necessarily a good estimate of cost of the nutrient the feedstuff is to provide.

Example: Soybean meal (47 per cent protein) at $375/tonne costs $0.80/kg of protein, while canola meal (37 per cent protein) at $240/tonne costs $0.65/kg of protein.

Availability of consistency of supply

- Is the desired feedstuff always available or is a storage facility necessary?
- Are the nutrient levels of the ingredients consistent? Soybean meal has traditionally been considered the standard protein, since the level is around 45 to 50 per cent crude protein, of which 85 per cent is digestible.

Nutrient levels The proportions and amounts of nutrients contained in the feedstuff will determine the final selection. If the price is right, but the feedstuff is not complementary, it is not a good buy.

Palatability Choice of ingredients may be determined by taste. Often, problems of worm seed mustard, burnt grains or moldy feeds may cause pigs to refuse the ration. If, for example, burnt grain is available at a very good price, special handling of the grain, such as mixing it with a good grain sample, or special cleaning may be required. This extra handling may offset the advantageous price.

Feed testing for maximum use of feed resources

Feed testing serves three major functions in preparing rations:

- It ensures that rations can be formulated for optimum use of the nutrients present.
- Serves as a quality control tool with home mixed rations. That means being sure the ration on paper is the same as the one the pigs are eating.
- Identifies deficiencies in existing rations.

Of the feeds used in Manitoba, 70 to 90 per cent of the total swine diet is composed of cereal grains. The remaining 10 to 30 per cent is either commercial supplements, or high protein feedstuffs, mineral and vitamin premixes. Unless an analysis, especially for protein, has been done on the grain, there is uncertainty as to the quality or adequacy of the ration.

The mixing instructions that accompany the supplements are usually based on the assumption that the grain is of average quality. If grain quality varies there could be an over-supplying or under-supplying of the essential nutrients. In either case, it is costly.

"It is best to feed test"

A look at Table 15 shows the variability of dry matter and protein content of the cereal grains tested in Manitoba over a five year period. For example, a

TABLE 15. ANALYSIS OF GRAINS — MANITOBA FEED TESTING LABORATORY 1977-1981

Grains	Dry Matter		Crude Protein	
	Average	Range	Average	Range
Barley	87.1	66.9 - 95.4	10.6	6.7 - 15.3
Corn	78.7	53.8 - 91.0	8.1	5.7 - 11.2
Wheat	88.0	68.6 - 93.0	14.6	9.3 - 21.0
Oats	90.3	76.8 - 95.4	11.5	8.0 - 15.7
Peas	87.2	76.7 - 93.0	21.5	19.1 - 24.2
Fababeans	85.7	68.1 - 95.5	24.5	14.0 - 29.1

barley sample may have a crude protein content of only 9.0 per cent. If the feed tag recommendations are based on 11.5 to 12.0 per cent crude protein in the grain, then the ration will be deficient in protein even though energy will be adequate.

Feed analysis can be used to check the accuracy of the mixing facility. If 850 kilograms of barley and 150 kilograms of a commercial supplement calculate out to 16 per cent protein, and subsequent analysis of a representative sample indicates a 20 per cent level, check the accuracy of the feed processing and mixing equipment.

In the case of registered feeds (complete feeds, supplements, or premixes) the manufacturer is responsible for the nutrient content. Several laboratories in the province can check these ingredients or rations for the producer or manufacturer. If satisfaction is not received from the feed company, the Plant Products Division of Agriculture Canada can be contacted (Winnipeg Office — (204) 949-2236). For custom mixed feeds, home mixed feeds or home-grown feedstuffs, Manitoba Agriculture provides a nutrient analysis and ration advisory service through its Feed Testing Laboratory. Private Laboratories in the province can also provide a nutrient analysis.

For formulating rations, feed analyses should be completed before pigs are put on feed. To be sure this is accomplished, submit sample early. A regular analysis for complete feeds includes moisture, crude protein, calcium and phosphorus. Other analyses are available upon request. These include crude fibre, nitrates, prussic acid, fat, ash, salt, urea, and some trace minerals. Consult your local Agriculture Representative for feed sample kits and information about fees.

Feed formulation and balancing diets

Pre-Ration information

Before formulating a ration, consider the following:

- How much feed is available.
- How many tonnes of oats, barley and other grains are on hand.
- What protein supplements or protein feeds and mineral and vitamin premixes are available.

Get a feed analysis of the individual feedstuffs. Do not rely on test weight (gm/half litre) or visual appraisals as an indication of protein levels. Be sure to test a representative sample of the total grain or protein crop.

Identify weight and age of the animals to be fed. Before balancing a ration for other nutrients, decide which feedstuffs will be used to provide the desired level of energy. Starter rations will contain more wheat or corn (which are high in energy content) than grower or finisher rations. Grower and finisher rations may contain more barley, since the energy requirement for pigs at this stage is lower.

The Pearson Square

There are several ways of calculating balanced diets (supplying the correct amounts and proportions of nutrients, in order to satisfy the requirements of the animal). A method referred to as the Pearson Square is often used because it is an easy method to understand, and uses simple calculations. The Pearson Square can be used to determine the mix of feedstuffs to supply the required amount of any nutrient. This method also allows for easy substitution if prices fluctuate, or supplies of various ingredients change.

Steps in Using the Pearson Square as shown in Example 1:

- Construct a square with the per cent protein of the two feed ingredients (barley 11.5 per cent protein, and protein supplement 40 per cent protein) in the two left corners of the square.
- Place the desired mixed protein level (for grower pigs 16 per cent) in the middle (this value must fall between the percentage of the nutrients supplied by each of the feedstuffs).
- Record the difference between the desired level and each of the ingredients in the diagonally opposite right-hand corners of the square (subtract along the arrows to get the answer at the head of the arrows).

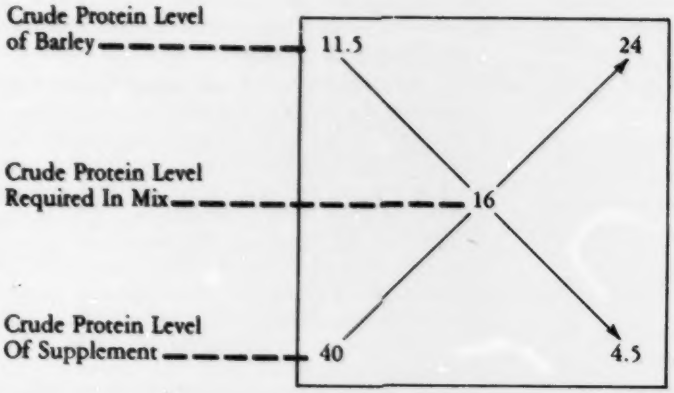
  In the example given, these differences represent the proportion of barley and supplement, (example 24 parts barley, and 4.5 parts supplement) which when mixed, will give 16 per cent crude protein. The total parts will be 4.5 + 24 = 28.5.
- To make a 1 tonne (1000 kg) mix, each figure is multiplied by 1000 and divided by 28.5 (the total parts in the mix).

The result is that 158 kg supplement and 842 kg barley are needed to provide the 16 per cent crude protein desired in one tonne of mix. *Always check to see if the other nutrients are present in sufficient quantities.*

Examples using the Pearson Square.

Example 1:

Your barley tests 11.5 per cent crude protein and you are mixing a 40 per cent Hog Supplement with the barley. You want to balance the ration at a 16 per cent crude protein level:



$$\frac{\text{Parts Barley} \times 1000}{\text{28.5 Total Parts}} = 842 \text{ kg}$$

$$\frac{\text{Parts Supplement} \times 1000}{\text{28.5 Total Parts}} = 158 \text{ kg}$$

28.5 Parts Total — 1,000 kg

RESULT: To balance one tonne of barley and supplement to the 16% crude protein level, you must use 842 kg barley for every 158 kg of supplement.

To check the amount of protein in the ration:

842 kg of barley (11.5% protein) supplies

$$\frac{842 \times 11.5}{100} = 96.8 \text{ kg of protein}$$

158 kg of supplement (40% protein) supplies

$$\frac{158 \times 40}{100} = 63.2 \text{ kg of protein}$$

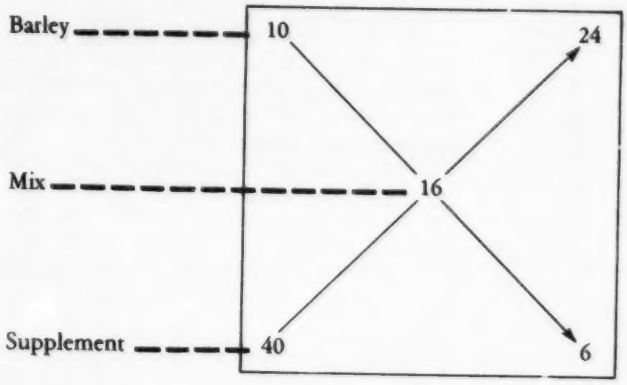
Total Protein in 1 Tonne of Ration (16%) — 160.0 kg of protein

1 Tonne = 1000 kg

NOTE: The level of other nutrients can be checked in the same manner.

Example 2:

If the barley tested 10 per cent crude protein, how much more supplement would be needed? Follow through the steps outlined on the previous page, using the protein content of this barley.



$$\frac{\text{Parts } 1000 \times 24}{30} = 800 \text{ kg}$$

$$\frac{\text{Parts } 1000 \times 6}{30} = 200 \text{ kg}$$

30 Parts Total 1,000 kg

RESULT: In this case, 42 kg more supplement is required per tonne of feed, or 800 kg barley to 200 kg supplement.

How do these two rations compare?

If barley is $90/tonne in both cases, and supplement is $198/tonne, then: (example 1)

842 kg barley x $.09/kg	=	$ 75.78
158 kg suppl. x $.198/kg	=	31.28
Cost of Feed Per Tonne		$107.06
Cost of Feed Per kg		$ .107

(example 2)

800 kg barley x $.09/kg	=	$ 72.00
200 kg suppl. x $.198/kg	=	39.60
Cost of Feed Per Tonne		$111.60
Cost of Feed Per kg		$ .112

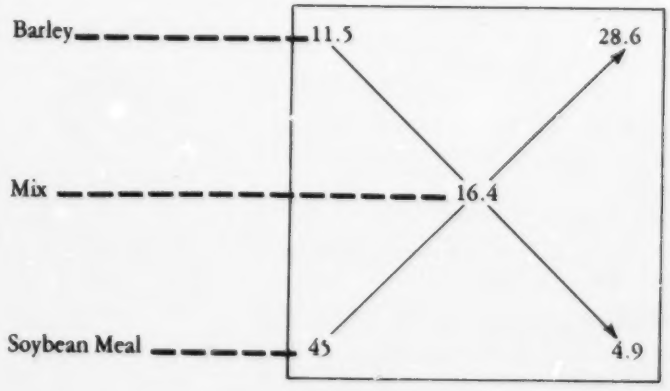
The ration in Example 1 is $4.54 cheaper per tonne than the ration in Example 2. This works out to .005¢ per kilogram. If one market pig consumes 320 kg, this difference would be .005 x 320 = $1.60 per hog marketed. Therefore, the higher protein barley resulted in more profit per pig marketed.

NOTE: If a high protein grain is used, the minerals and vitamins supplied in the 40 per cent supplement may not be sufficient if the ration is formulated only on protein content. To utilize the higher protein content of some Manitoba grown grains, rations may have to be formulated using a protein feed (soybean meal) combined with a mineral-vitamin premix (see example 3), or if the producer uses a large volume of supplement, he can get protein supplement especially blended with the appropriate levels of minerals and vitamins.

Example 3: Grain, Protein Supplement, and a Third Ingredient (Mineral-Vitamin Premix).

If barley, soybean meal and premix are being used, a slightly more complicated calculation is required for protein balance. First, it is necessary to determine how much vitamin-mineral premix is to be added to the mix. Either follow the manufacturer's recommendation, or calculate needs according to the amount of vitamins and minerals present in the premix and in the feed. Then mix according to the vitamin and mineral needs of the type of swine being fed.

If a premix is used in a 16 per cent grower ration at 25 kg tonne, the protein required in the mix must be in the remaining 975 kg of ration (assuming no protein is provided by the premix). A 16 per cent ration should contain 16/100 x 1000 = 160 kg of protein per tonne. Since one must allow for the 25 kg of premix in the ration, which provides no protein, the protein level of the remaining 957 kg of ration must be increased to 16.4 per cent (160/975 x 100 = 16.4) to balance the final ration to 16 per cent. The square is used as follows:



Parts Barley x 975 / 33.5 = 832 kg

Parts Soybean Meal x 975 / 33.5 = 143 kg

33.5 Parts Total 975 kg

The ration contains:

832 kg barley
143 kg soybean meal
25 kg premix (vitamin-mineral)
1000 kg or 1 tonne

Again, the protein content of the ration can be checked:

832 kg of barley provide $\frac{832 \times 11.5}{100}$ = 95.7 kg of protein

143 kg of soybean meal provide $\frac{143 \times 45}{100}$ = 64.3 kg of protein

Total Protein in the Ration is:
(95.7 + 64.3 = 160.0) (16%) 160.0 kg/tonne

Example 4: More than One Grain and/or More Than One Protein Source

To use the Pearson Square when more than one grain is used, the proportion of the different grains to be used must be determined, and then the protein level of the grain mix can be used in the square (see Example 4).

For a nursing sow ration, suppose 5 per cent alfalfa meal, 5 per cent canola meal, and soybean meal are to be used with a grain mix of two parts barley to one part wheat. A mineral-vitamin premix is to be added at 35 kg per tonne. A 15 per cent crude protein ration is desired. The crude protein levels of the various feedstuffs are barley — 11.0 per cent, wheat — 13.5 per cent, alfalfa meal — 15 per cent, soybean meal — 48 per cent, and canola meal — 37 per cent.

In a 15 per cent crude protein ration, 150 kg of protein are required per tonne of feed (total needs). The fixed amounts of alfalfa meal and canola meal (5 per cent each) will provide:

- 50 kg of alfalfa meal (5 per cent of ration) supplies 15/100 x 50 = 7.5 kg of crude protein.
- 50 kg of canola meal (5 per cent of ration) supplies 37/100 x 50 = 18.5 kg of crude protein.

Therefore, crude protein needed from the remaining ingredients (barley, wheat and soybean meal) is 150 kg (total needs) minus 18.5 kg from canola meal, minus 7.5 kg from alfalfa meal = 124 kg. 50 kg/tonne (5 per cent) of alfalfa meal must be added as well as 50 kg (5 per cent) of canola meal and 35 kg of premix (135 kg total). Since the amounts of premix, alfalfa meal and canola meal, are constant, the amount of grain (barley-wheat) and soybean meal are adjusted to give the proper balance. Thus, 1000 - 135 = 865 kg of soybean meal, barley and wheat must supply 14.3 per cent crude protein (124 x 100/865 = 14.3 per cent).

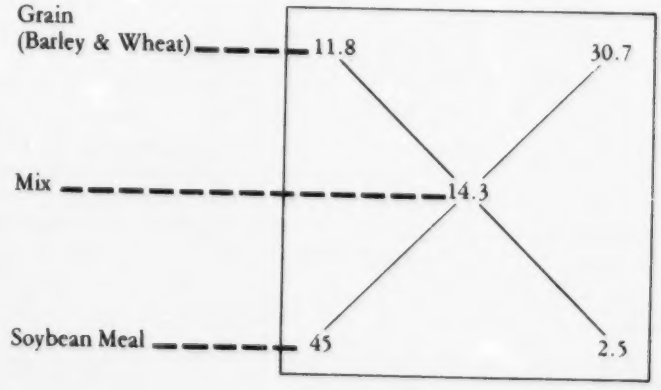
Calculation of protein content of grain mixture:

2 parts barley + 1 part wheat

$$= \frac{(2 \times 11) + (1 \times 13.5)}{3} = 11.8 \text{ per cent}$$

crude protein.

The examples show how much more complicated ration formulation becomes as the number of ingredients used in the ration are increased.



$$\frac{30.7 \times 865}{33.2} = 800 \text{ kg}$$

$$\frac{2.5 \times 865}{33.2} = 65 \text{ kg}$$

33.2 Total Parts 865 kg

2 parts barley + 1 part wheat = 800 kg
3 parts = 800 kg
1 part = 267 kg wheat
2 parts = 533 kg barley

Thus, the ration consists of:

Wheat (1 part)	267 kg
Barley (2 parts)	533 kg
Alfalfa meal (5 per cent)	50 kg
Canola meal (5 per cent)	50 kg
Soybean Meal	65 kg
Premix (mineral-vitamin)	35 kg
	1000 kg

For a greater variety of feedstuffs, a much more complicated calculation is required. High speed digital computers are commonly used by feed company nutritionists to formulate rations for swine involving thousands of calculations in a fraction of a second. The information required for computer formulation is:

- analysis of each feed to be used, preferably test results, although book values (feed composition tables) are sometimes used.
- cost of each ingredient and feedstuff delivered to the point of mixing.
- class of pig to be fed, and nutrients required for that class
- any constraints on levels of the various feeds to be used, or on the nutrients desired (example: maximum of 5 per cent fish meal in starter ration).

Examples of typical swine rations and further information on ration formulation are found in the Manitoba Agriculture Agdex 440-52 Factsheet *Balancing a Swine Ration*.

Feed processing techniques

Grinding and rolling Crushing, grinding and rolling appear to be equally effective when the processes have prepared the grain to the same degree of fineness. Swine feeds are processed for two main reasons:

- Digestibility is slightly improved by grinding the feeds for growing pigs (Figure 6), and more so in older animals. Older pigs do not chew their feed to the same extent, making the saving by grinding greater.
- Grinding or rolling allows easier and more uniform mixing of minerals, vitamins, proteins, and grains. It helps keep to a minimum the sorting of ingredients during mixing, or by the pigs when feeding.

Grains which have a considerable amount of hull (like oats), should be finely ground. Barley and corn should be medium ground. Wheat, which has a tendency to go pasty or bridge in the feeders, should be coarsely ground. Suggested screen sizes for grinding grains are given in Table 16.

TABLE 16. SUGGESTED SCREEN SIZES FOR COMMON CEREAL GRAINS

Oats	2 mm or 3 mm
Barley & Corn	2 mm or 3 mm
Wheat	6 mm

NOTE: If numerous whole kernels appear in the processed ration, check the condition of the screen and hammers and the screen size.

Pelleting and crumbling Pelleting and crumbling are alternatives to feeding meal (ground feeds). Feed waste is reduced by pelleting and dust is not as great a problem. Pigs can not sort feed ingredients. Settling out does not occur and less space is needed for storage. In some cases, better rates of gain have resulted from pelleting feeds. Pigs fed pelleted diets usually require 5 to 8 per cent less feed per unit of gain than those on meal.

However, potential benefits of pelleting may be offset by additional costs, and net returns may be equal. Pellets are used most effectively when the ration price is high, and feed waste is costly (example: baby pig rations).

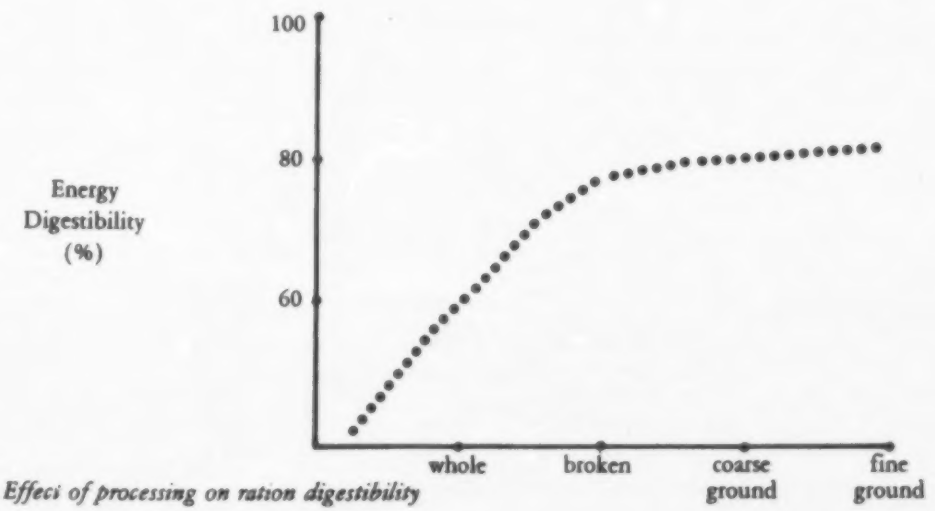


Figure 6. Effect of processing on ration digestibility

High moisture feeds High moisture barley or wheat (20 to 30 per cent moisture) appears to be as effective as dry barley or wheat, in terms of dry matter required per kilogram of gain. An experiment at the University of Alberta indicates that high moisture grains, preserved with a 2/3 acetic acid and a 1/3 propionic acid mixture, show comparable results on a dry matter basis to those obtained using low moisture grains from the same source.

Cooking By law, garbage must be cooked to destroy disease organisms before feeding. The regulations regarding the cooking and feeding of garbage to pigs are administered by Health of Animals, Agriculture Canada.

Cooking potatoes increases digestibility. Fed raw, 7 kg of potatoes is approximately equal to 1 kg of grain. When cooked, 4 kg of potatoes is approximately equal to 1 kg of grain. Cooking grain does not increase its value enough to warrant the expense.

Feeding methods

Various feeding methods are used to control the intake of nutrients and thus influence growth, production and final profit. Methods of feeding found satisfactory for one operation, may not be satisfactory for another.

Full feeding (Ad Libitum) "Ad libitum" (ad lib) feeding means the pigs get all the feed they want. Full feeding has certain advantages. It reduces labour costs, makes feeding management somewhat simpler and increases growth rate. However, there are disadvantages. If pigs tend to fatten early, grades will be reduced. Maximum intake can be hampered if feed goes stale or if trough space is inadequate, causing competition for food. Good management will eliminate these problems.

NOTE: *When self-feeders are used, care must be taken to ensure they are adjusted properly to prevent waste.*

Young growing pigs use feed economically, so should be encouraged to eat as much as possible. Depending on the breed of pigs raised, previous market grades and production costs, restricted feeding may be more economical once pigs reach 60 kg.

Restricted feeding Restricted feeding involves feeding less feed than the pigs can consume. It has advantages with certain types of swine. Restricted feeding can be accomplished by reducing the amount provided, the time feed is available, or adding fiber to the diet to restrict the amount of nutrient consumed.

- *Gilts and sows* Restricted feeding is recommended for bred gilts and sows to keep weight gains to a minimum. Over-feeding breeding stock is inefficient, can reduce litter size, and increase baby pig mortality. Bulky fibrous feeds can be used to lower energy content and effectively keep breeding females from getting too fat.

  The skip-a-day program is a form of limit feeding in which breeding stock have access to a self-feeder every second day for a set period of time (2 to 8 hours). The amount of feed is controlled by the length of time the sows are left on the self-feeders. Weight gains can be effectively controlled when sows are group-fed in this manner.

- *Growing and finishing pigs* The use of restricted feeding for these types of pigs is questionable. Although grades may be improved, the additional cost of slower gains, increased labor and lower barn throughput, may offset the benefits of improved grades. If animals are to be limit-fed, it should not be done until they weigh at least 60 kg, and feeding levels should not go below 85 per cent of full feed.

- *Sexing of pigs* Gilts grow slower than barrows, but produce leaner carcasses. Barrows tend to fatten more rapidly than females, so restricted feeding can improve carcass quality but will reduce rate of gain. However, the reduced gain and longer time to market weight (from seven to fourteen days) must be balanced against the value of leaner carcasses.

  If possible gilts and barrows should be divided into separate pens. Gilts should be fed ad lib.

Liquid feeding This involves mixing feed with water, either before delivery to the pens, or in the trough. In some situations, it appears to increase feed efficiency and improve rate of gain slightly. Any advantage shown for wet feed over dry feed is probably a reflection of food waste and lung irritation on dry dusty diets.

The method of feeding best suited to a particular operation depends on the number of pigs to be fed, the amount of grain available, the rate of gain desired, the type of pig, and the amount of labour available.

Glossary

Amino Acids — are the digestion products of proteins. From amino acids in the diet, pig meat proteins are made by joining the amino acids together into proteins.

Amylase — an enzyme that breaks down starch.

Anemia — a condition of the blood characterized by decreased hemoglobin concentration with or without decreased erythocytes (red blood cells) which results in reduced oxygen-carrying capacity per unit volume of blood.

Antibiotics — represent a group of chemical compounds produced biologically by certain plants or micro-organisms, usually a fungus which possess bacteriostatic or bacteriocidal properties.

Caecum — a blind pouch at the beginning of the large intestine. Important in digestion of fiber in the horse. About the same as an appendix in man.

Calorie — unit of quantity of energy; amount of heat required to raise the temperature of one kilogram of water 1 degree C.

Colon — is a portion of the large intestine starting at the caecum.

Dietary essential amino acids — those amino acids that cannot be synthesized by the animal at a rate to meet the animal's requirement and therefore, must be present in adequate levels in the diet.

Digestibility — refers to the amount of a given nutrient that is retained by the body for use. The amount of nutrient in feed minus the amount in the feces.

Enzyme — an organic catalyst. A substance produced by living cells, that speeds up chemical reactions.

Ergot — a fungus which affects cereal crops, particularly rye. Kernels are replaced by purplish black elongated hard bodies.

Esophagus — the part of the digestive system which joins the mouth to the stomach.

Feces — another term for manure.

Fiber — the relatively undigestible part of plants. Consists of the parts of the plant that makes up the outer coating of seeds, cell wall structures. Used for support by the plant.

Goiter (or Goitre) — is an enlargement of the thyroid gland caused primarily by a lack of iodine in the diet.

Hemoglobin — is the protein molecule in the blood that is responsible for carrying oxygen to the tissues.

Hepatosis Dietetica — a liver disorder associated with selenium deficiency. It normally occurs in pigs between the ages of 3 and 15 weeks.

Lipase — enzyme which acts on lipids. Lapase acts on triglycerides in the intestine making them available for digestion by the pig.

Membrane integrity — means keeping the membranes (cell wall structures) together.

Metabolism — complex of physical and chemical processes involved in the maintenance of life.

Mulberry Heart Disease — a disease associated with Vitamin E — selenium deficiency. It is characterized by sudden death of apparently healthy pigs at any age, although it most commonly occurs at 5 - 6 weeks or in pigs weighing 40-55 kg.

Necrotic enteritis — is the chronic form of infection by the bacteria Salmonella Choleraesuis in pigs. The disease organism causes inflamation of the stomach and intestines.

Osteomalacia — "softening of the bone" represents a decrease in the mineral content of adult bone as a result of a failure of the formation of new bone to keep pace with the constant mobilization of calcium and phosphorus in the dynamic state.

Pancreas — a gland in the abdomen next to the small intestine. It secretes enzymes into the small intestine to aid in digestion.

Parakeratosis — a nutritional deficiency disease caused by a deficiency of zinc. Disease appears mange-like with hard crusted material on the upper layers of the skin.

Pepsin — is an enzyme secreted in the stomach which acts on protein helping to break it down into amino acids.

ppm — parts per million.

Precursor — a substance from which another substance is formed.

Rennin — is an enzyme secreted in the stomach of pigs that causes milk to curd.

Rickets — rickets represents a disturbance of the mineral metabolism in such a way that the calcification of the growing bone does not take place normally.

Trypsin inhibitor — is a substance found in plants and other tissue which prevents the enzyme trypsin from acting on proteins in the gut.

Other related publications:

Manitoba Agriculture factsheets:

— Nutrient Requirements of Swine, Agdex 440-52.

— Protein and Amino Acid Sources for Swine, Agdex 440-64.

— Feed Additives for Swine, Agdex 440-67.